SIEMENS

MAGNETOM

MR

Functional Description

Avanto

Avanto Dot

Espree

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The Table of Contents is found in the Bookmarks tab card of Acrobat. Further information can be found in the Acrobat "Help" function.

Links

This document has a built-in hyperlink system to facilitate navigation. Text links are recognizable by their BLUE color. Graphical links are usually denoted with a triangle ◤ placed in the upper left corner of any box within a graphic. Where this could not be realized an attempt has been made to indicate a link using some other means. Links, however, can be recognized when the cursor changes to a hand when placed over a link.

Screen Shots

Throughout this document are several screen shots taken from different software versions. They are intended to be used to explain a point in general and are not intended to reflect any actual version. Therefore, deviations to any actual software version is likely.

Section

1

System

Introduction

The Avanto and Espree are the first of three systems belonging to a product line based on a new hardware platform. This document covers both the Avanto and Espree systems.

The Avanto and Espree share a common platform of hardware components consisting of Electronics and Gradient cabinets, RF hardware and hosts. Components differing between these systems are the magnet, gradient and body coils. Slight differences are also be found in the Patient Table.

The Avanto System

The MAGNETOM Avanto provides 1.5 Tesla field strength with 50 cm FoV, the strongest gradients available on the market and Tim technology, the new standard MRI imaging.

The Avanto system variations:

- MAGNETOM Avanto: Tim [76x32] SQ-engine
- MAGNETOM Avanto: Tim [76x18] SQ-engine
- MAGNETOM Avanto: Tim [76x18] Q-engine
- MAGNETOM Avanto: Tim [32x8] Q-engine

Avanto Dot

Dot is a software technology first introduced with the MAGNETOM Aera and Skyra systems and the VD line software. It is available also as an option for Avanto systems.

The Dot – Day optimizing throughput – technology enables users to optimize image quality and consistency and maximize efficiency by providing such features:

- adapt scans to accommodate for different patient types and patient conditions (Dot is personalized)
- ensure consistent image quality by guiding users through scan procedures via intelligent pre-defined workflows (Dot is guided)
- reduce patient set-up times by automating patient positioning and aiding in proper PMU set up (Dot is automated)

The Espree System

The MAGNETOM Espree was created to meet the needs of patients who wanted a better, less intimidating MRI experience. MAGNETOM Espree combines CT-like comfort with Tim.

The Espree system variations:

- MAGNETOM Espree: Tim [76x32] DZ-engine
- MAGNETOM Espree: Tim [76x18] DZ-engine
- MAGNETOM Espree: Tim [76x18] Z-engine
- MAGNETOM Espree: Tim [32x8] Z-engine

The diagram below provides an overview of the Avanto and Espree Hardware components. The blocks can be clicked to jump to that part of the Functional Description.

Figure 1 *MAGNETOM Avanto / MAGNETOM Espree System Block Diagram*

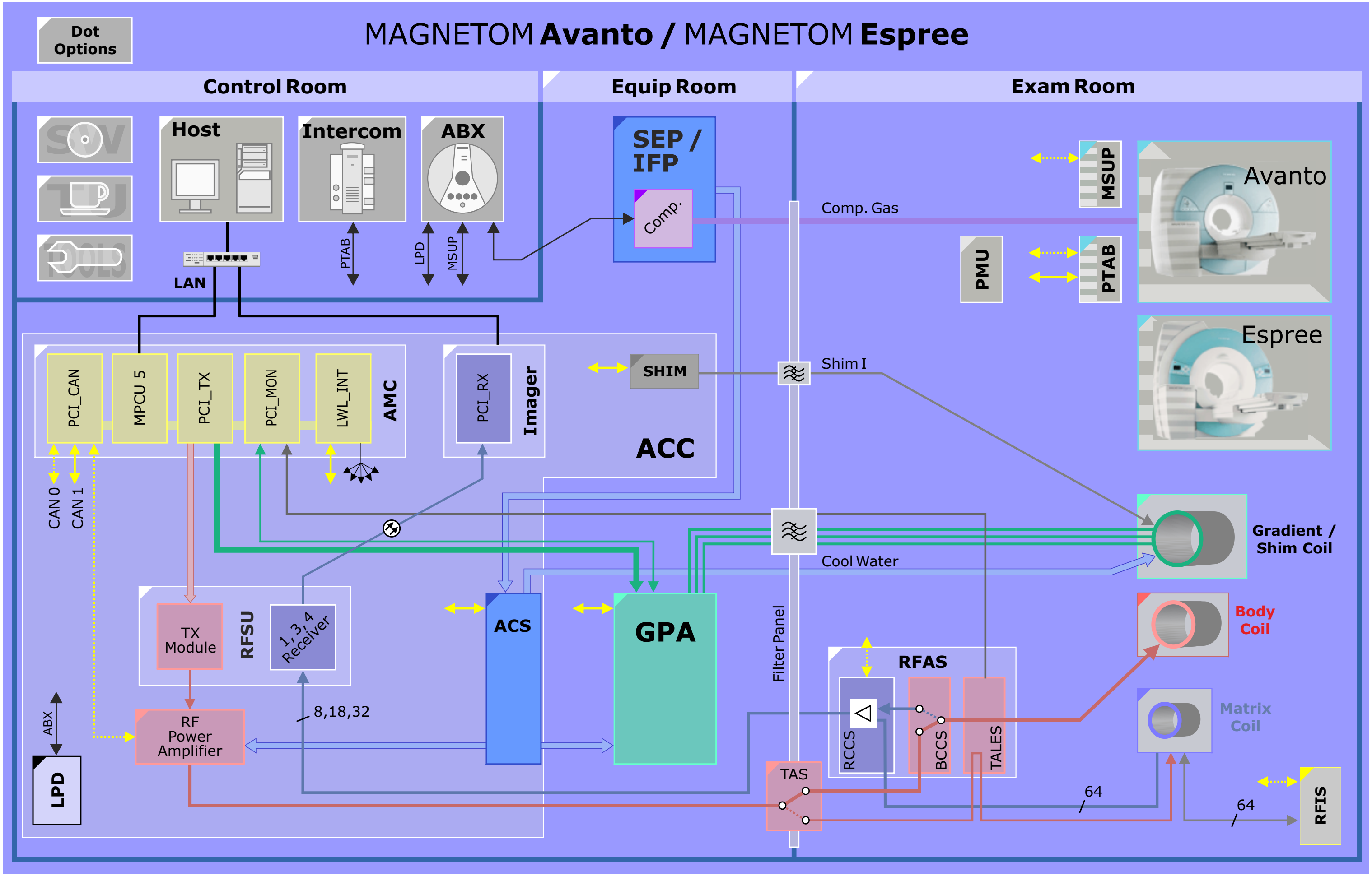


Figure 2 Equipment Room Components

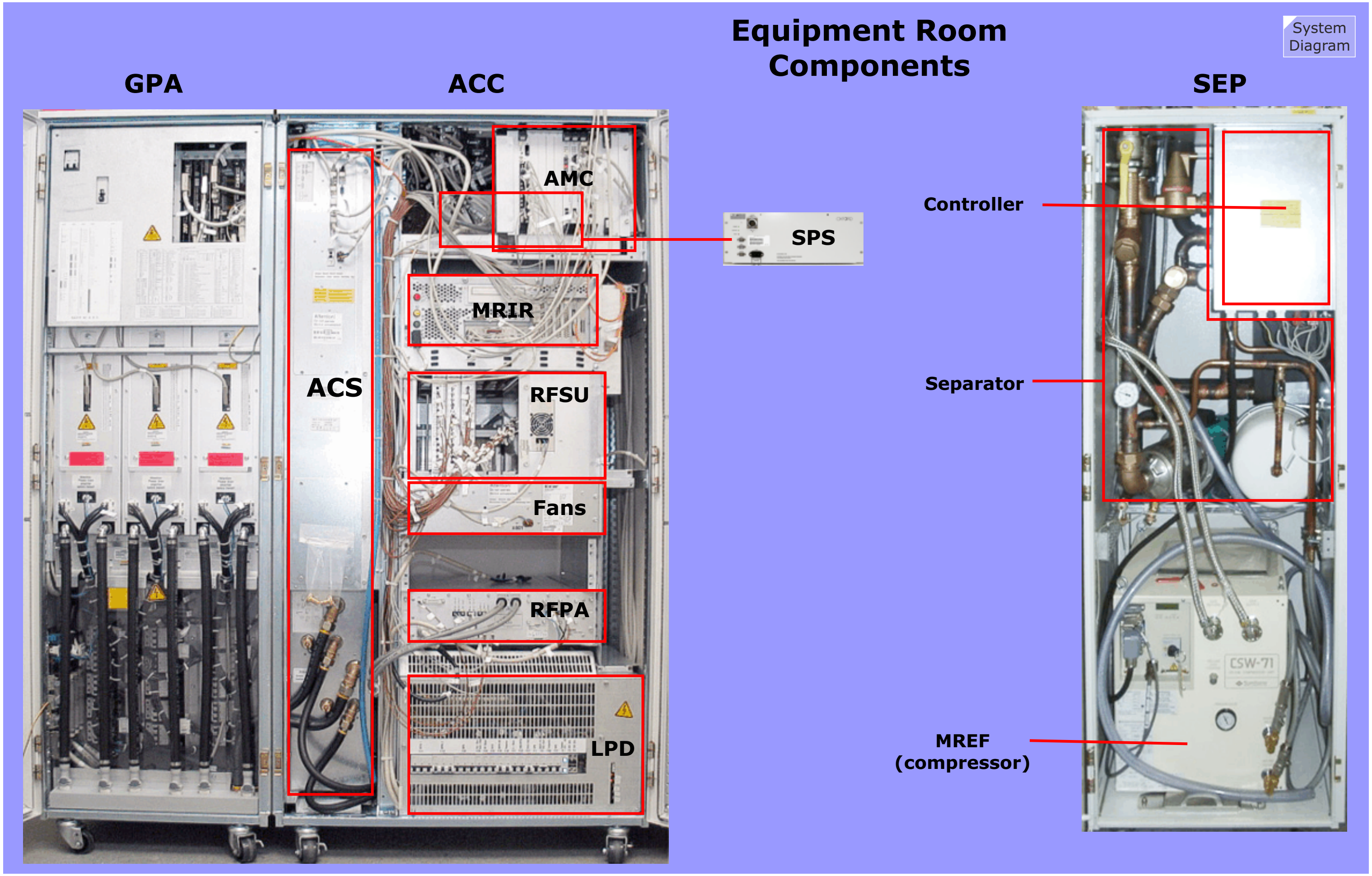
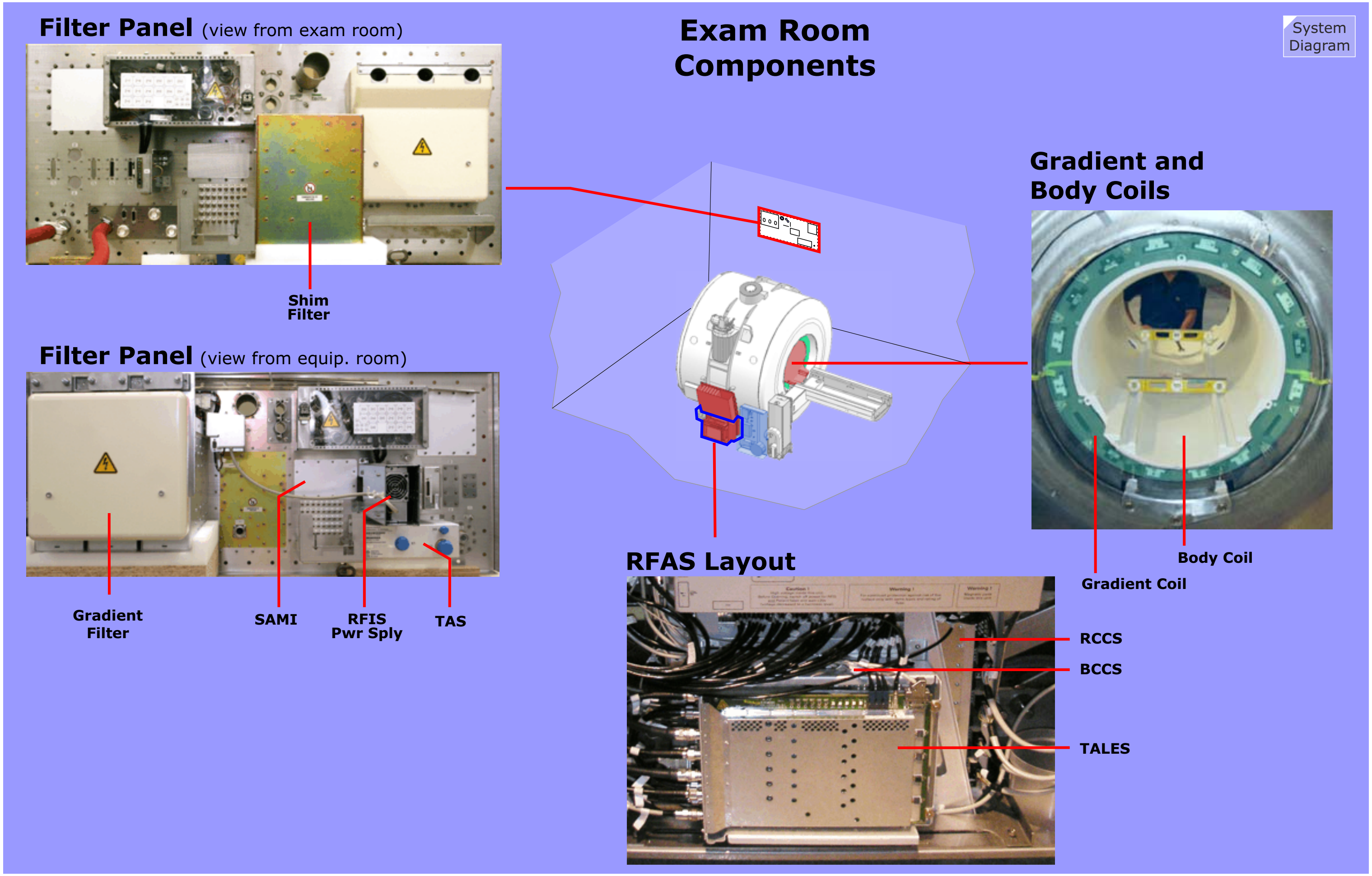


Figure 3 Exam Room Components



List of Abbreviations:

System Documentation Manuals:

DIA	Diagram Manual
FUN	Functional Description
INS	Installation Manual (2 volumes)
LOG	Logbook
PG	Planning Guide
ROP, REP	Replacement of Parts
TSG	Trouble Shooting Guide

1000Base-T	1000 Mbit per second, based on twisted pair cable
100Base-TX	100 Mbit per second, based on twisted pair cable
10Base-T	10 Mbit per second, based on twisted pair cable
ABX	Alarm Box
ACC	Advanced Control Cabinet
ACS	Air Conditioning System
ADC	Analog Digital Converter
AGP	Accelerated Graphics Port
AMC	Advanced Measurement Control
AS	active shield
AVC	Active Vibration Control
AVL	Auxiliary Vent Line
BC	Body Coil
BLOB	binary large object
BNC	Bayonet connector named after Neil-Concelman
BPL	Backplane
BR	Bildrechner (image reconstruction)
CAN	Controller Area Network
CCS	Cabinet Cooling System
CCU	Current Control Unit
CD-R	CD Recorder
COCS	Cost Optimized Cooling System
Codec	Compressor and Decompressor
COM	Component communication
COOL	Cooling system
CORA	Cost Optimized RF Amplifier
CORDIC	Coordinate Rotation in Digital Computer
CORE	Clinically Optimized Regional Exams
COSLIO	CAN Open SLIO
CP	circular polarized
cPCI	compact PCI
CPU	Central Processing Unit
CV	Coil Voltage (TALES output) or computer voice
CW	Control Word
DDR SDRAM	Double Data Rate Synchronous Dynamic RAM
DIMM	Dual In-Line Memory Modules
DORA	Double Resonant RF Amplifier (RFPA)
DSL	digital subscriber line
DSP	Digital Signal Processor
DSV	Diameter Spherical Volume
DVD	Digital Versatile Disk
ECC	eddy current compensation
ECG	electro-cardiogram
ECL	enhanced current lead
EFI	External Field Interference
EIS	External Interference Shield
EPR	electronic patient record
ERDU	emergency run-down unit
ETL	ERDU test load
FCL	Fixed Current Lead
FOC	fiber optic cable
FoV	field of view
FPGA	Field Programmable Gate Array
FRU	Field Replacable Unit
FSC	Full Scale
FWHM	Full Width at Half Maximum
GC	Gradient Coil
GPA	Gradient Power Amplifier
GSSU	Gradient Small Signal Unit
HDD	Hard Disk Drive
HF	High Frequency
ICE	Image Calculation Environment
IDE	Integrated Device Equipment

IDEA	integrated development environment for Application	NCO	Numerical Controlled Oscillator
IEEE	Institute of Electrical and Electronics Engineers	NOE	Nuclear Overhauser Effect
IF	Intermediate Frequency	NTP	network time protocol
IFP	Interface & Filter Panel	NUMARIS	Nuclear Medicine Acquisition and Reconstruction Imaging Software
IGBT	isolated gate bipolar transistor	OEM	original equipment manufacturer
iPAT	integrated Parallel Acquisition Technique	OS	operating system
IQ	Image Quality	OVC	Outer Vacuum Chamber
ISO	International Standard Organization	P4	(Intel) Pentium 4
LAN	Local Area Network	PAT	Parallel Acquisition Technique
LC	Local Coil	PCB	printed circuit board
LO	Local Oscillator	PCI	Peripheral Component Interconnect Bus
LP	linear polarized	PCIx	extended PCI bus
LPD	Line Power Distribution (same as PDS)	PDAU	Physiological Data Acquisition Unit
LVD	Low Voltage Differential	PDS	Power Distribution System (same as LPD)
LWL	Lichtwellenleiter (fiber optic cable)	PMU	Physiological Measurement Unit
MAG	Magnet	PORA	Power Optimized RF Amplifier
MARS	Measurement and Reconstruction System	POST	power on self test
MC	Measurement Control	POW	Power Distributor (PDS, LPD)
MDH	Measurement Data Header	PS/2	Personal System /2
MDSD	Move during scan drive	psiA	psi Absolute (ref. to vacuum)
ME	Magnet Electronic	psiG	psi Gauged (diff. to atmosphere)
MKO	Multi Kern Option (multi nuclei spectroscopy)	PTAB	Patient Table
MOCO	Motion Correction	PTR	Pulse Tube Refrigerator
MOD	Magneto Optical Disk	QLA	quick latch - subminiature coax RF connector
MOFI	(De)-Modulation and Filtering	RAID	Redundant Array of Independent Disks
MPCU	Measurement, Physiological & Communication Unit	RAM	Random Access Memory
MPS	magnet power supply	RCCS	Receive Coil Channel Selector
MPSU	Magnet Power Supply Unit	RFAS	RF Application System
MR	Magnetic Resonance	RFFIL	RF Filter
MRC	MR (Main) Console	RFIS	RF Infra Structure
MREF	Refrigerator (i.e. Helium Compressor)	RFPA	RF Power Amplifier
MRIR	MR Image Reconstruction system (imager)	RFSU	RF Signal Unit
MRSC	MR Satellite Console	RFSWD	Radio Frequency Safety Watchdog
MSUP	Magnet Supervision	RTL	real time clock
MWL	Modality Work List	RTT	removable table top
MWS	Mantelwelle Sperre (RF Trap)	RX	receive, receiver
N	connector type named after Paul Neill	SAMI	Spectroscopy Amplifier Interface

SaTs	Symphony, a Tim system
SCA	Single Connection Adapter
SCSI	Small Computer System Interface
SCT	Sequence Control Task
SEP	Separator cabinet
SeSo	Service Software
SGA	switched gain amplifier
SHARC	Super Harvard Architecture Computer
SLIO	Serial Linked Input/Output
SSB	Single Sideband
STIMO	stimulation monitor
syngo	synergy, let’s go
SW	Software
TALES	transmit antenna level sensor
TAS	Transmit Antenna Selector
Tim	Total imaging matrix
TX	transmit
USB	Universal Serial Bus
VGA	Video Graphics Array
VID	Video (patient monitoring)
VPN	virtual private network
YAPS	Yet Another Parameter Set

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Section

2 Software

Introduction

This description will give a *general* overview of the *syngo* MR software and its components. The main emphasis will be the service relevant aspects of the software. In most cases, repairing software problems will entail either fixing a bad configuration or re-installing software entirely. But, to satisfy curiosities, some background knowledge of the software and what is it SUPPOSED to do will also be presented.

Overview

Software has now become, by far, the single most expensive component of our MR systems. It has and is being developed by more than 300 programmers across four continents and is continually growing in functionality, size and number of unexpected features.

To gain our bearings, lets first define the software components running on the system. In general, the **software** components running in the system can be classified into one of three groups:

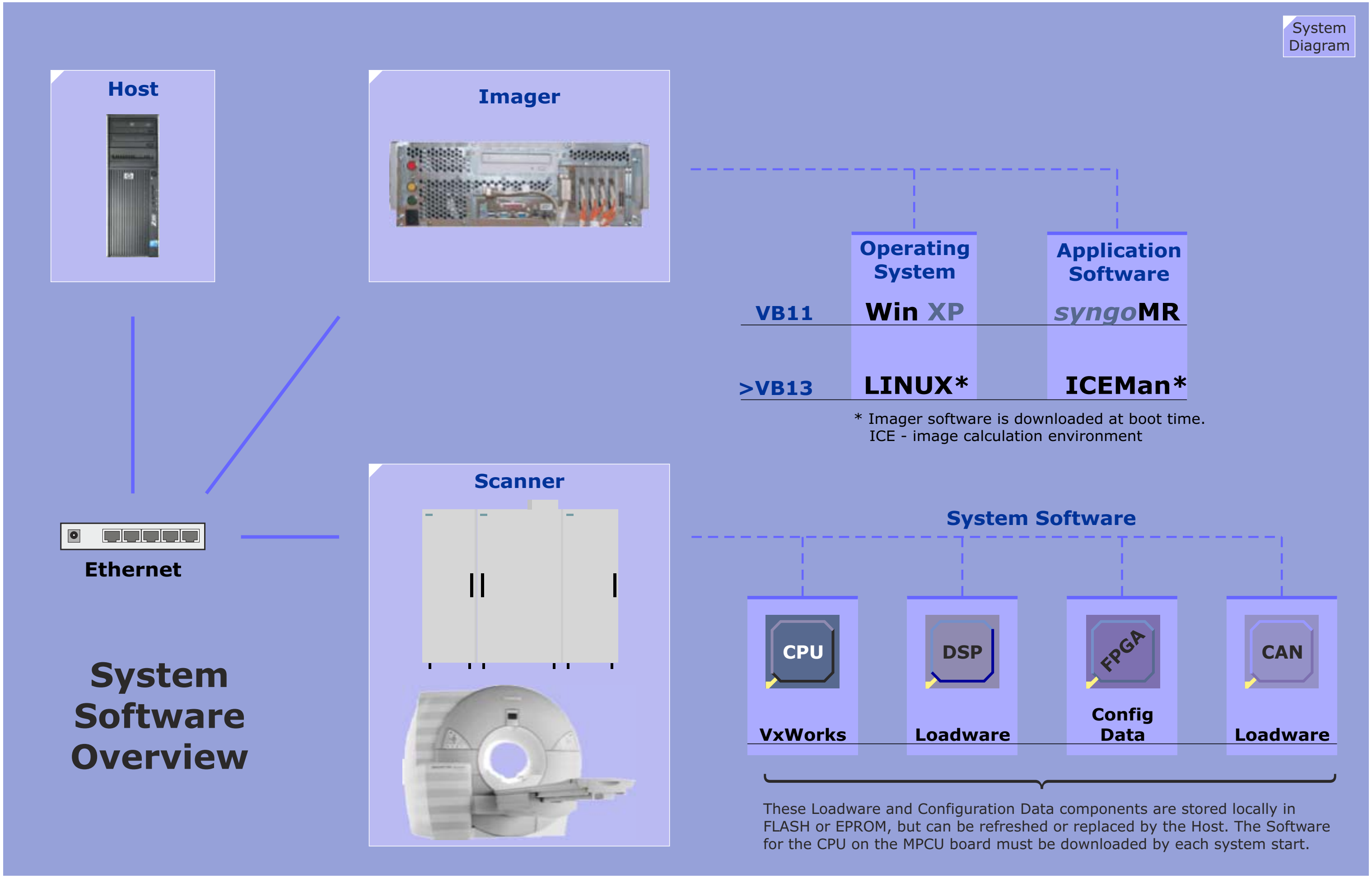
- Operating System (OS)
- Applications (*syngo*MR)
- Scanner Peripheral Control (CPU and FPGA loadware)

Of course, there can be no software without hardware. The **hardware** components running one or more of these software groups:

- MRAWP (MRC) and MRWP (MRSC) **Host**
- MR Image Reconstruction MRIR (**Imager**)
- **Scanner** hardware peripheral units such as the Measurement, Physiological & Communication Unit (MPCU) and various low-level hardware and peripheral controllers

The software components mentioned above which require interaction from and with the user or service engineer will be looked at more closely, that is primarily the software running on the Host. The Imager software is invisible to the user and generally does not require configuration or handling and therefore will not be covered, although some tips will be given which may help determine whether it is running properly. The scanner software is discussed in the Control System section.

Figure 4 *System Software Overview*



Host Software

The Host software includes a Microsoft OS and the *syngo* MR® software applications required for setting up scan protocols, image post-processing, image archiving functions and other organizational tasks such as providing the imager and hardware controllers with software during the scanner boot up procedure.

The software differences between MRAWP and MRWP are determined by the **configuration** after a software installation.

syngo®

syngo is a software platform developed especially for medical systems and applications and provides the basis for modality specific control and applications as well as applications for a wide range of post-processing and other radiological workflow-related functions. *syngo* has a modular structure and can be divided into these major functional blocks (refer to Figure 5):

- the *syngo* Platform
- the *syngo* Applications
- the *syngo* User Interface

syngo Platform

The *syngo* platform utilizes a Common Software Architecture (CSA) which provides fundamental functionalities such as basic image processing tools, a DICOM data model, an image database and networking capabilities.

A **Patient Browser** enables access to and allows one to navigate through the patient Database. Images in the database can be sent, exported and imported to and from remote network nodes or local mass storage media. The Patient Browser is **configurable** to adapt to individual workflow preferences.

syngo Applications

The common *syngo* applications are the same for all syngo implementations across all modalities and include the Viewing, Filming and 3D processing functionalities.

MR Specific *syngo* Applications

The application software developed for MR systems includes:

- Exam - image producing application
- Mean Curve
- ARGUS Flow
- Perf MR - Neuro Perfusion
- BOLD
- Spectroscopy Evaluation
- Neuro 3D - 3D Offline fMRI

syngo User Interface

syngo provides a user friendly graphical interface providing a common interface across all modalities, workstations, radiological and clinical information systems implementing the *syngo* software.

The *syngo* software together with the MR *specific application packages* is called *syngo* MR software

Much of the software just mentioned can be configured and adapted to the workflow requirements and personal preferences. This will be discussed throughout this section.

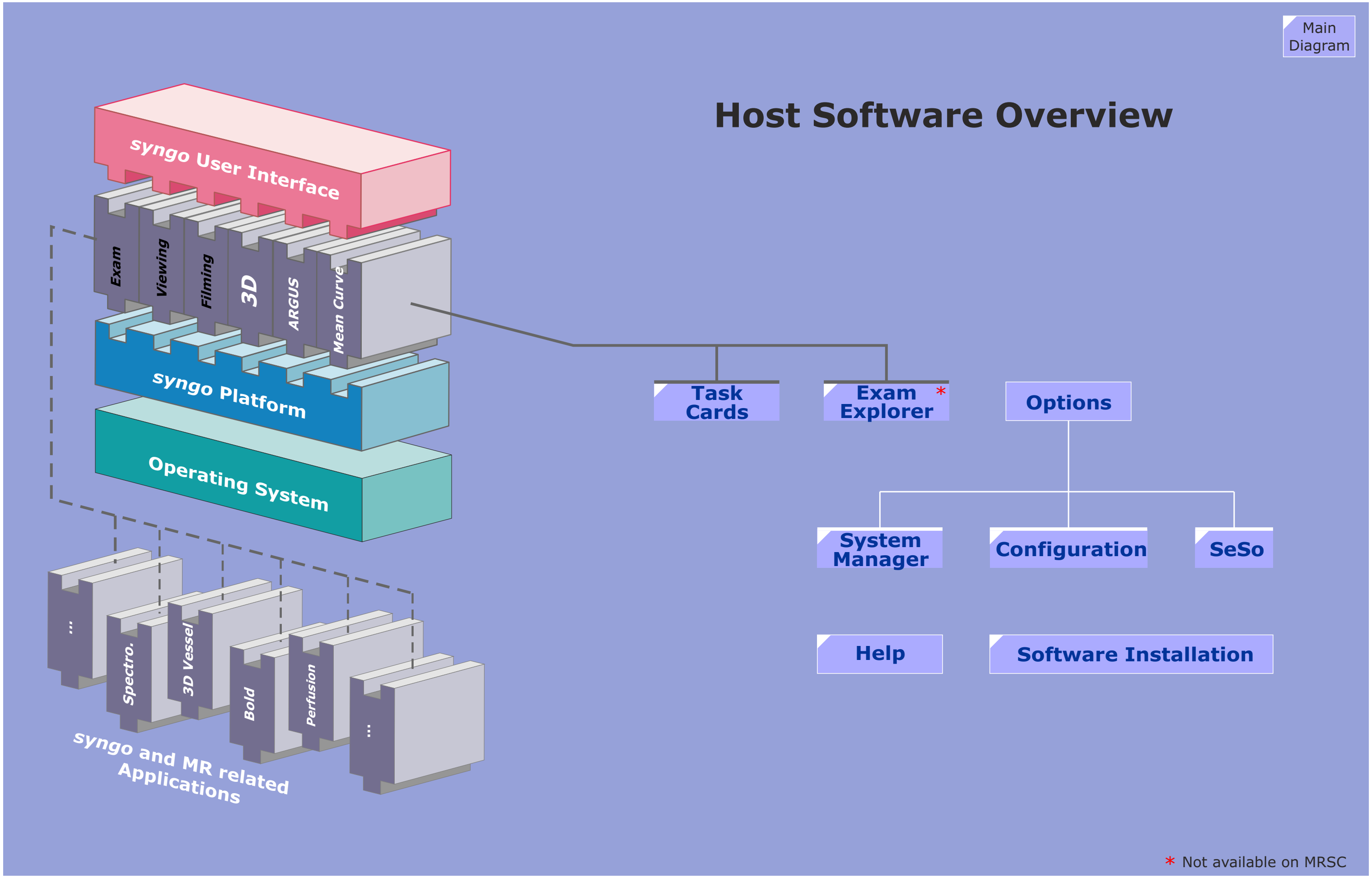
Imager Software

The Imager is runs a 64-bit Linux OS. Imager software is downloaded at system boot.

Scanner Software

The downloading of the scanner software is described in the CONTROL section.

Figure 5 *Host Software Overview*



syngo MR

Task Cards

The *syngo* and *syngo*MR Applications are loaded onto Task Cards which are automatically started when the Host is booted or can be started manually.

The arrangement of the task cards reflects routine workflow in the hospital or practice and their layout supports the examination procedure.

Task Cards which are produced by the syngo software factory and available on all *syngo*-based modalities are:

- Viewing
- Filming
- 3D (option)

The **Filming** Task Card will only be loaded after a DICOM camera has been configured. If a DICOM camera is not physically available, it is possible to configure a dummy camera in order to get the Filming Task Card. This task card is an integral part of syngo and does not require additional licensing.

The **3D** Task Card is an optional package requiring additional licensing.

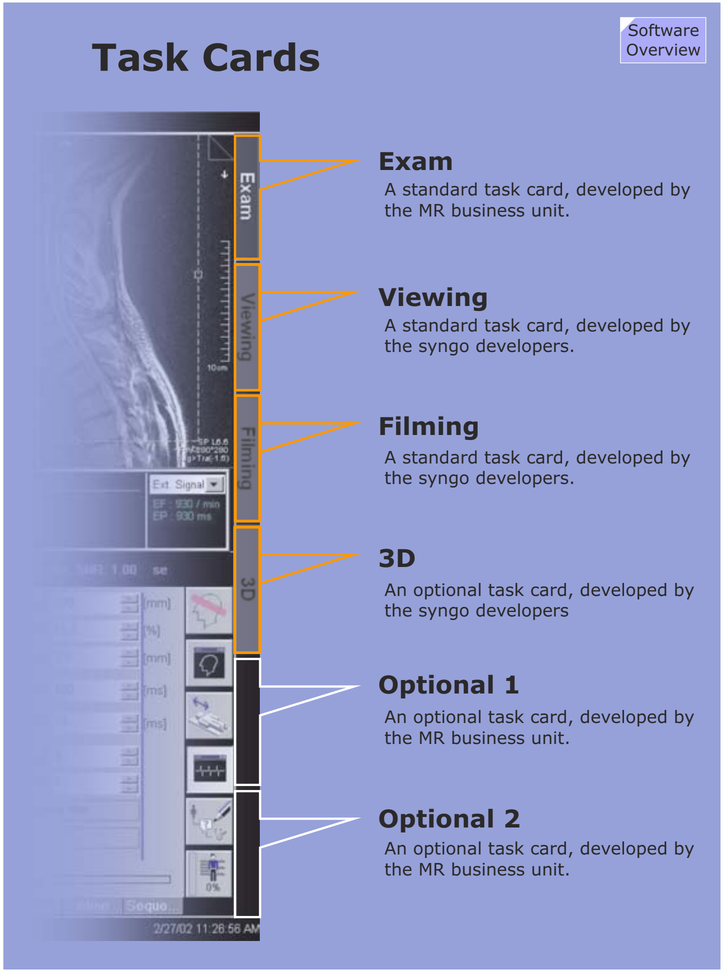
syngo MR specific Task Cards

- Exam
- **Argus**
- **Bold**
- **Mean Curve**
- **Spectroscopy**
- **3D Vessel View**
- **Perfusion**

Task Cards in **orange** are optional

The **Exam** Task Card is used to define and run MR examinations and is only available on the MRAWP. All other MR specific task cards are optional and will require additional licenses to be enabled.

Figure 6 *syngo MR Task Cards*



Licensing

The 3D optional Task Card and optional software application packages require licenses before they can be used. Licenses must be ordered explicitly for the MRAWP or MRWP. A license issued for the MRAWP will not run on the MRWP or vice versa.

Licenses can only be ordered from either the Licensing Center in Forchheim, Germany or from your Uptime Service Center or Regional Service Center in your country or time zone.

Task Card Menus

Figure 7 *The Menus*

Patient Browser menu

Patient Applications Transfer Edit View Filter Evaluation Sort Private Applications Options Help

Viewing Task Card menu bar

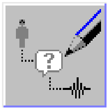
Patient Applications Transfer Edit View Image Tools Evaluation Scroll System Options Help

Filming Task Card menu bar

Patient Applications Edit Film Image System Options Help

All functions and commands found under these menus are described in minute detail in the Operators manual. The descriptions in this section covers only those functions that are service relevant.

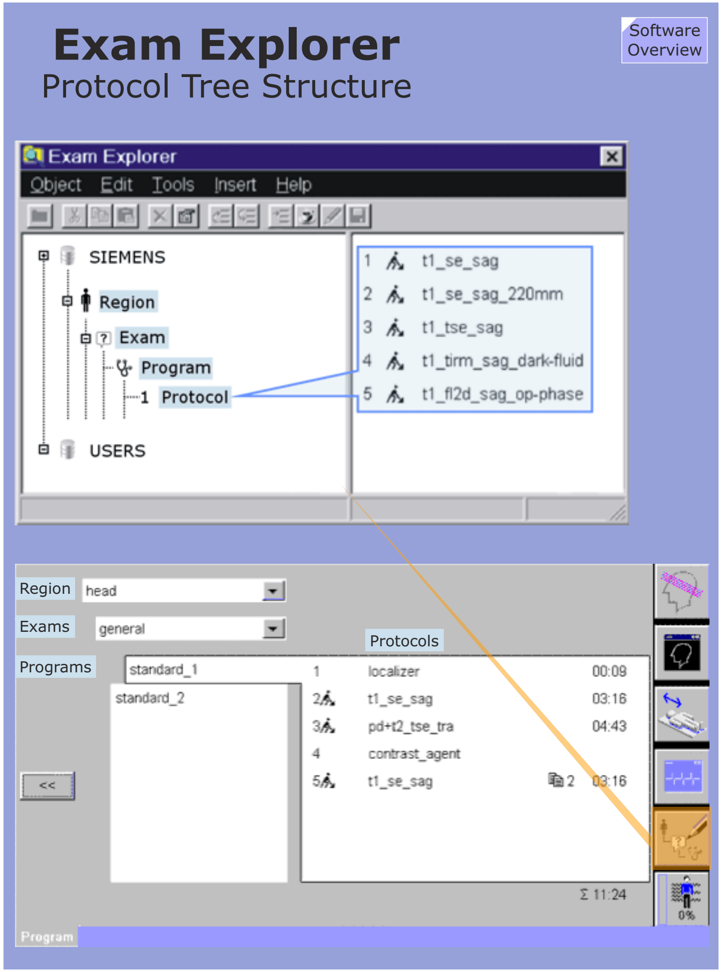
Exam Explorer



The Exam Explorer is a program to view and manage the examination protocols using a graphical interface, a la Microsoft's Windows Explorer. With the Exam Explorer it is possible copy or move protocols between **Regions**, **Exams** and **Programs** using the same drag and drop techniques know from the Microsoft Windows operating system. Right-clicking the protocol brings up a context menu providing commands to modify, rename, copy or delete protocols.

The Exam explorer can be opened from the Exam task card by either select **View** > **Exam Explorer** from the main menu or via the icon show above.

Figure 8 *Exam Explorer*



The Protocol Trees

Protocols are found under two main groups: **SIEMENS** and **USER**. The protocols located under the SIEMENS tree are factory defaults and read only, they cannot be modified. The USER programs can be modified and are used by the customers for their examinations.

Protocols are organized within a strict hierarchy as shown in Figure 8. The top level consists of **Regions.** Regions correspond to the anatomical region to be examined. Regions consist of **Exams,** which in turn contain **Programs** which are a grouping of **Protocols**.

System Manager

The System Manager provides status information of the Host, Imager and MR scanner. It is invoked over the menu: **System** > **Control**.

Host Card

The System Manager / Host card displays the status of the loaded applications. The Exam-Task, Viewing-Task, Filming-Task and the 3D-Task are normally running (green arrow up). Optional tasks which are not loaded are marked with a red arrow down.

Applications which are hanging and not responding can be closed and restarted without having to shut down *syngo* MR or the operating system. It may work. But then again, it may not.

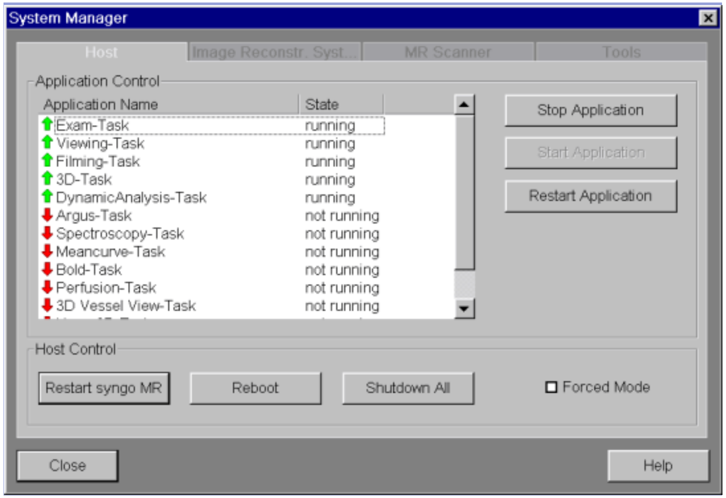
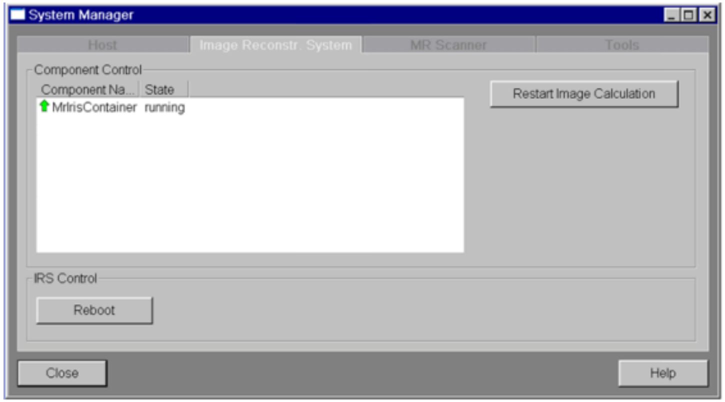


Image Reconstruction System Card

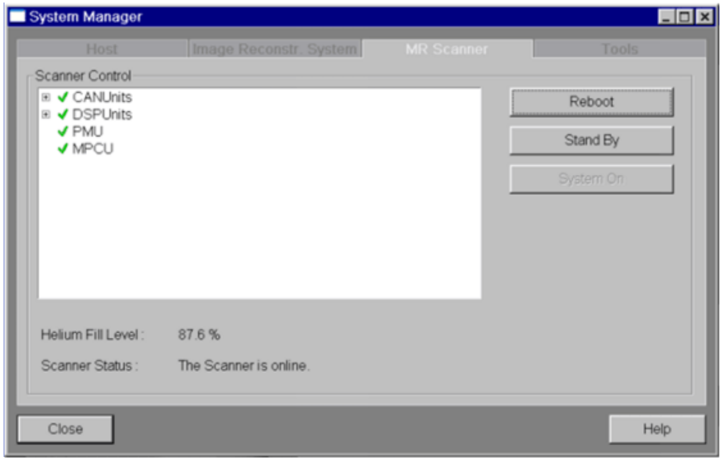
The Image Reconstruction System card displays the applications running on the Imager. From here you can reboot the imager hardware or attempt to restart the application servers.



MR Scanner Card

The state information is displayed for all monitored hardware components (i.e., have CAN components (SLIOs or Modules) or CPUs) within the MR scanner. These are listed under "Component Name". The current status of the components (OK, Not OK) is shown in the State column. The State flag here indicates that all conditions required for an "OK" state have been met, i.e., no errors or faults occurred or is in an undefined state. The list is updated automatically. During the reboot phase, the message "The Scanner is not online" will be displayed. When all scanner components are up and running "The Scanner is online" is displayed.

The **System On** and **Stand By** buttons can be used to turn the scanner components on and off. The **Reboot** function is necessary to reset the NOT OK state if an error occurred.

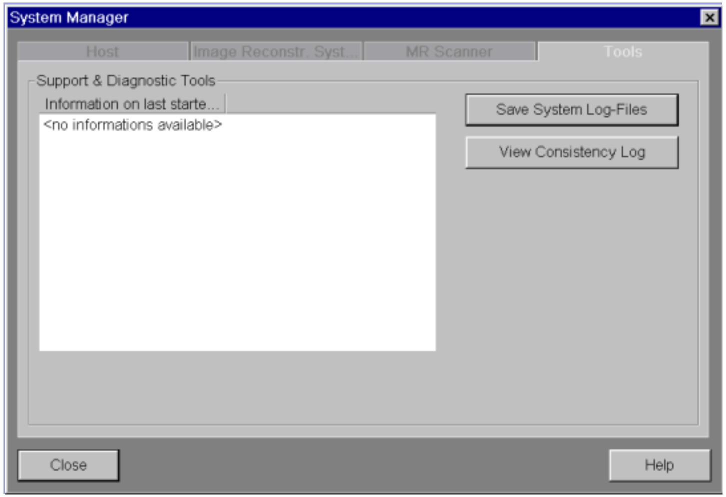


Tools Card

The Tools card is used to acquire diagnostic information or check important system files. If a software error occurs during scanning, it is recommended to create a MrSaveLog file immediately. It contains valuable diagnostic information valid at the time the error occurred. It is stored in the C:\MedCom\MriDiagnostic folder as a ZIP file.

The MR Consistency-Checker checks the system files for changes every time the system boots. The result is saved in a log file. You can view the content of this file in the Support & Diagnostic Tools window by clicking the View Consistency Log button.

WARNING	**Never install additional, unreleased software on the system. Doing so could replace existing system files and corrupt the scanner software.**



Configuration

Regional Settings

The user interface language and the keyboard settings can be configured under *Options > Configuration > Regional Settings*.

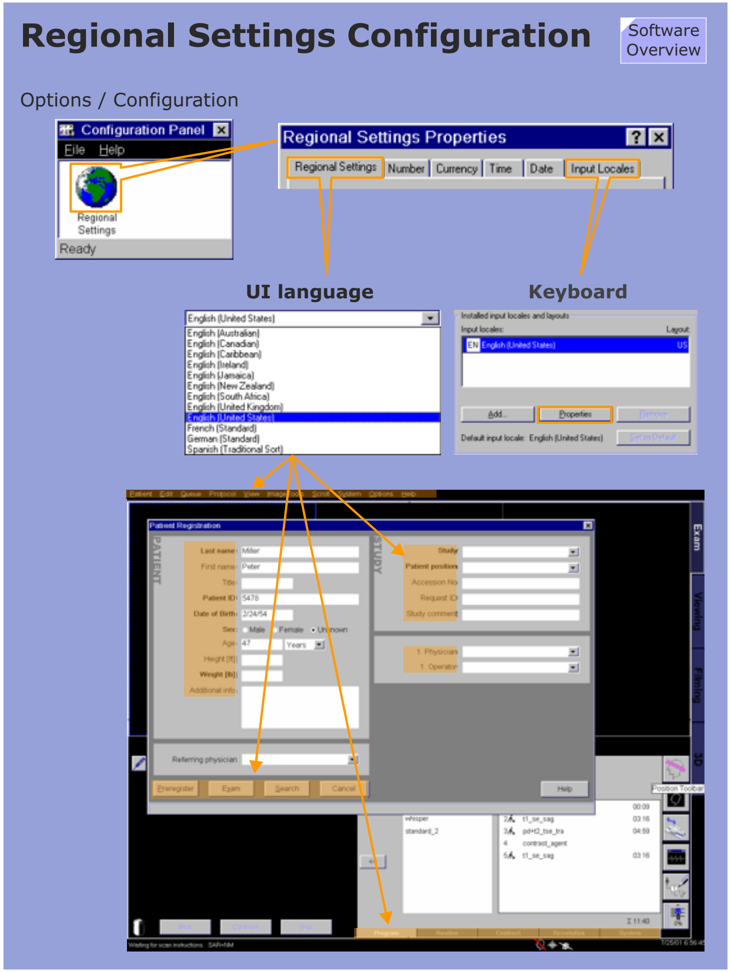
The language selection made here in the Regional Settings menu applies only for the Task Card menus, user interfaces and all fields (marked by the areas in red in Figure 9) within pop-up windows as well as for the application online help.

NOTE An exception is the Service Software interfaces which are available only in the english language.

The language of the data displayed within the white fields in the Patient Browser and Patient Registration UIs is determined by the **DICOM Character Set**.

Setting up the time, including the daylight saving time, is discussed in Service Software.

Figure 9 *Regional Settings*

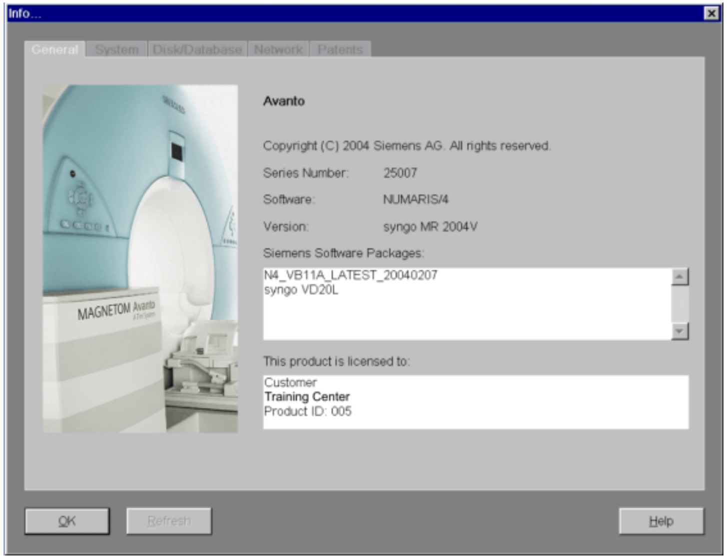


Help > Info

syngo MR also displays information about your scanner system. This includes information regarding memory capacity and availability. Select the menu **Help** > **Info** menu item.

General Card

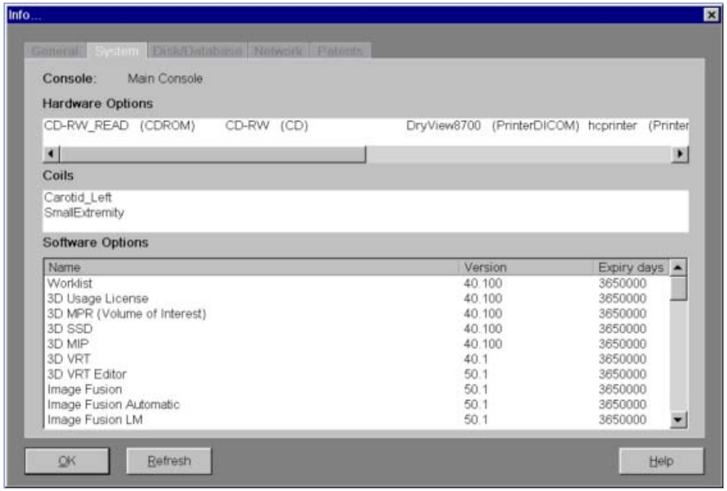
General system information is required, e.g. when a customer contacts Siemens Service regarding problems. Problems can be solved more quickly if we know the serial number of the system and the software version.



System Card

The System card provides further information about the scanner system. Here you will find information about hardware and software options installed as well as the available coils.

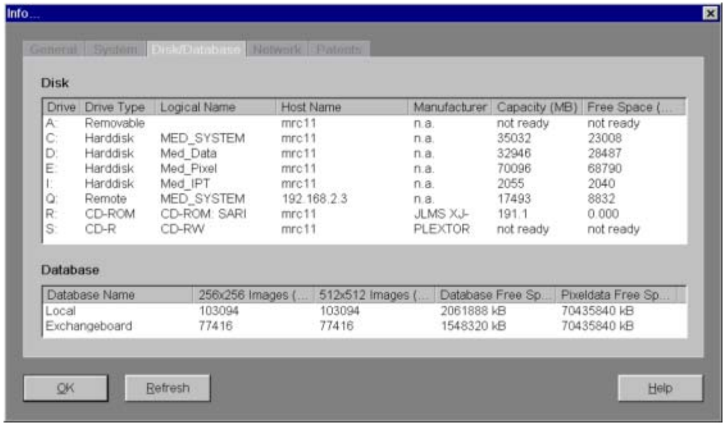
Also, the expiration date (if applicable) of software option licenses are shown.



Disk/Database Card

The **Disk** list displays all physical and logical (network) drives as well as their capacities and available space, expressed in MB and number of images.

All local databases are listed under Database. You are also shown how many images can still be stored in each matrix.

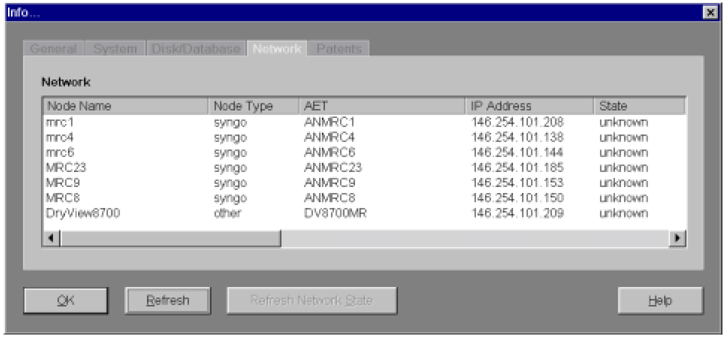


The following information is displayed:

- Name of the database
- Number of images 256 x 256 matrix images that can still be stored
- Number of images 512 x 512 matrix images that can still be stored

Network Card

If your console or satellite console is connected to a network, you may view network-specific information on the Network card such as the node names (computer names) and IP addresses.

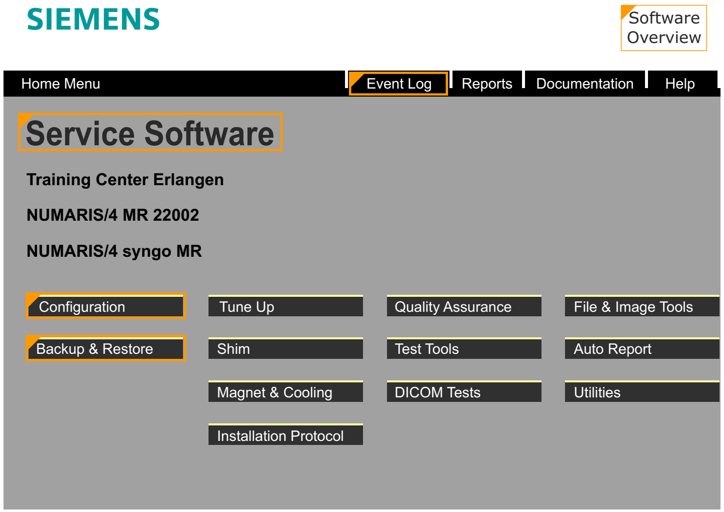


Service Software (SeSo)

Overview

After selecting Local Service in the menu Options Service and typing in the required password, the SeSo platform (shown below) will be displayed.

Figure 10 *Service Software User Interface*



SAM - Service Access Manager

SAM prevents or limits access to the various service functions via a password protection. Services levels can be purchased by a customer or even third party service organizations according to the level of their expertise or competence. Service passwords are limited in time and must be renewed after a time period which is determined by Siemens.

Local Access

SAM password protects the different service levels which allows the access of the available features to certain persons only.

Customer: The first level is accessible without password by the operator. Here only configuration parameters can be displayed.

In addition this level is used automatically if the operator selects the Event Log in the menu Options Service Eventlog.

Remote Access

If wanting to log onto a system remotely there are three modes the local operator can select:

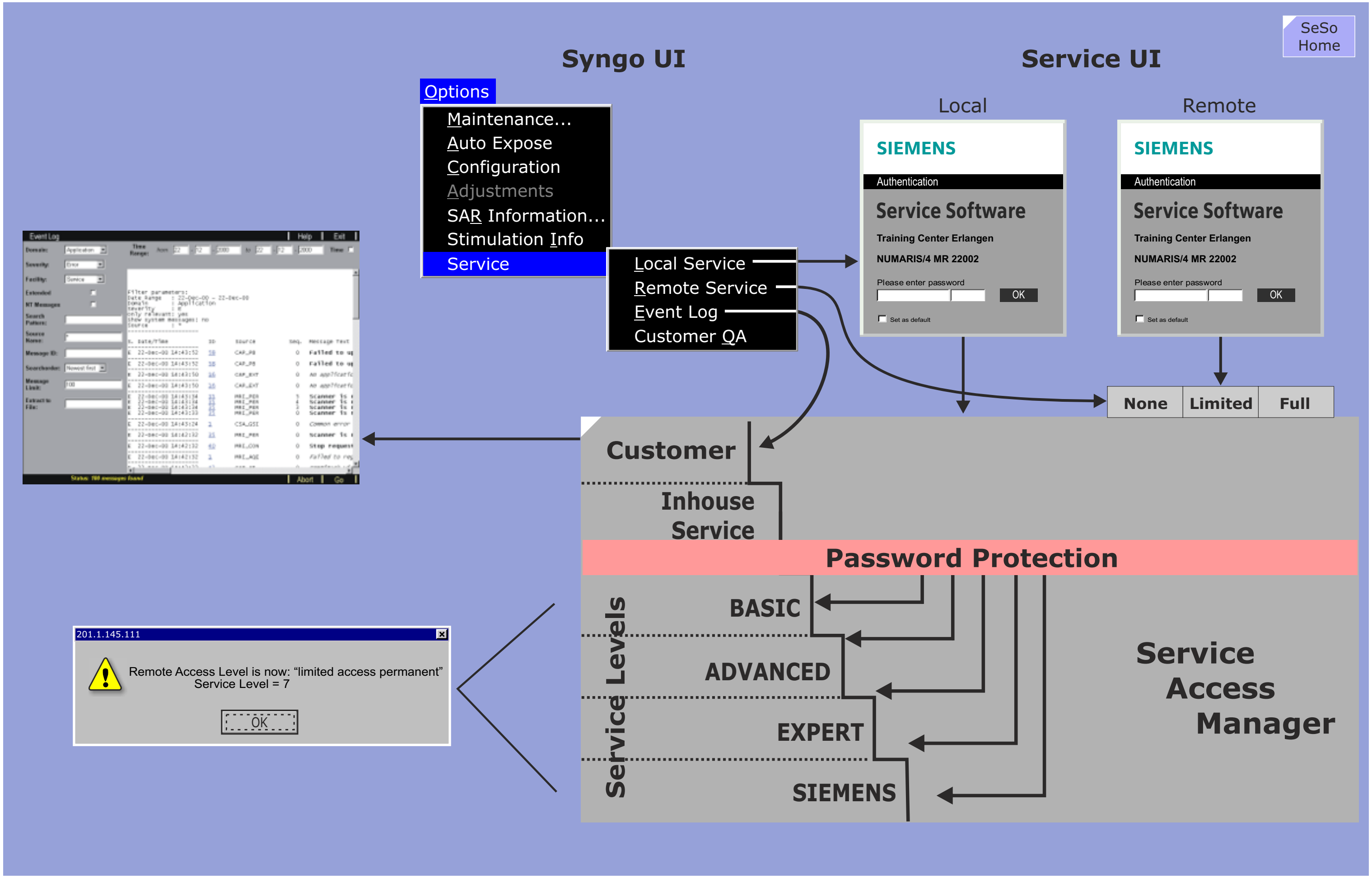
No Access - remote system access is denied and any pre-established connection will be immediately discontinued.

Limited Access - In this mode the remote connection is granted access privileges that allow only read / look type functions e.g. reading the Event Log, transfer images files etc.

Full Access - In this mode the operator relinquishes control and the remote connection is given full control over the system. The mouse and keyboard will be locked and the screen will blocked. In this mode the remote session can perform service tests and system checks (QA). One limitation is no automated patient table movements will be allowed, for obvious safety reasons.

Service Level	Remote				Local
	No Access	Limited	Limited Permanent	Full	
Customer					QA (customer) Configuration (system ID)
In-house service	NO remote access possible	Functions the same as Limited Permanent, but limited in time.	Configuration (view) Backup (auto)	Configuration (edit) Restore (manual)	Backup & Restore (manual)
Basic			Service QA (view) Utilities: • Send Message • Process (list) • Component Mgr (list)	Service QA (scan) Tune Up Utilities: • Escape to OS • System (start/stop) • Process (start/stop) • Component Mgr (start/stop)	Tune Up
Advanced			Event Log Reports	Test Tools DICOM Test Tools	
Expert			File & Images Tools		
Siemens			Documentation Installation Protocol (view) Remote Application Support		Documentation Install Protocol (edit)

Figure 11 *Service Access Manager*



Event Log

In order to understand the different possibilities which can be selected in the Event Log, the following overview should be helpful. Note there are three sources of event messages:

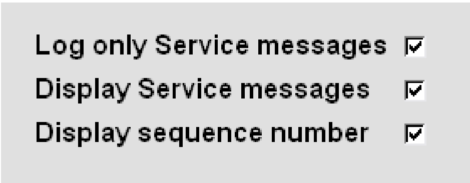
- the Windows OS
- Remote service (SAM)
- *syngo* MR

Regardless of the source, all messages are written into the same Event Log.

Pre-Filters

There is an additional pre-filter of the *syngo* MR messages that can be configured in the service software (see figure below). Enabling the "Log only Service messages" filter will block messages that are not service relevant (this should ALWAYS be enabled). The "Display service messages", when enabled, allows service messages to be entered (should also ALWAYS be enabled). The "display sequence number" will sort out the sequence of the error messages when more than one message is created at the same time. This is very useful since the first message is usually the one caused by the actual error, all following are often only the result of the first.

Figure 12 *syngo MR Message Filters*



These switches are set per default in the SeSo Configuration. If they are not set... well, we haven't noticed any difference.

Post Filters

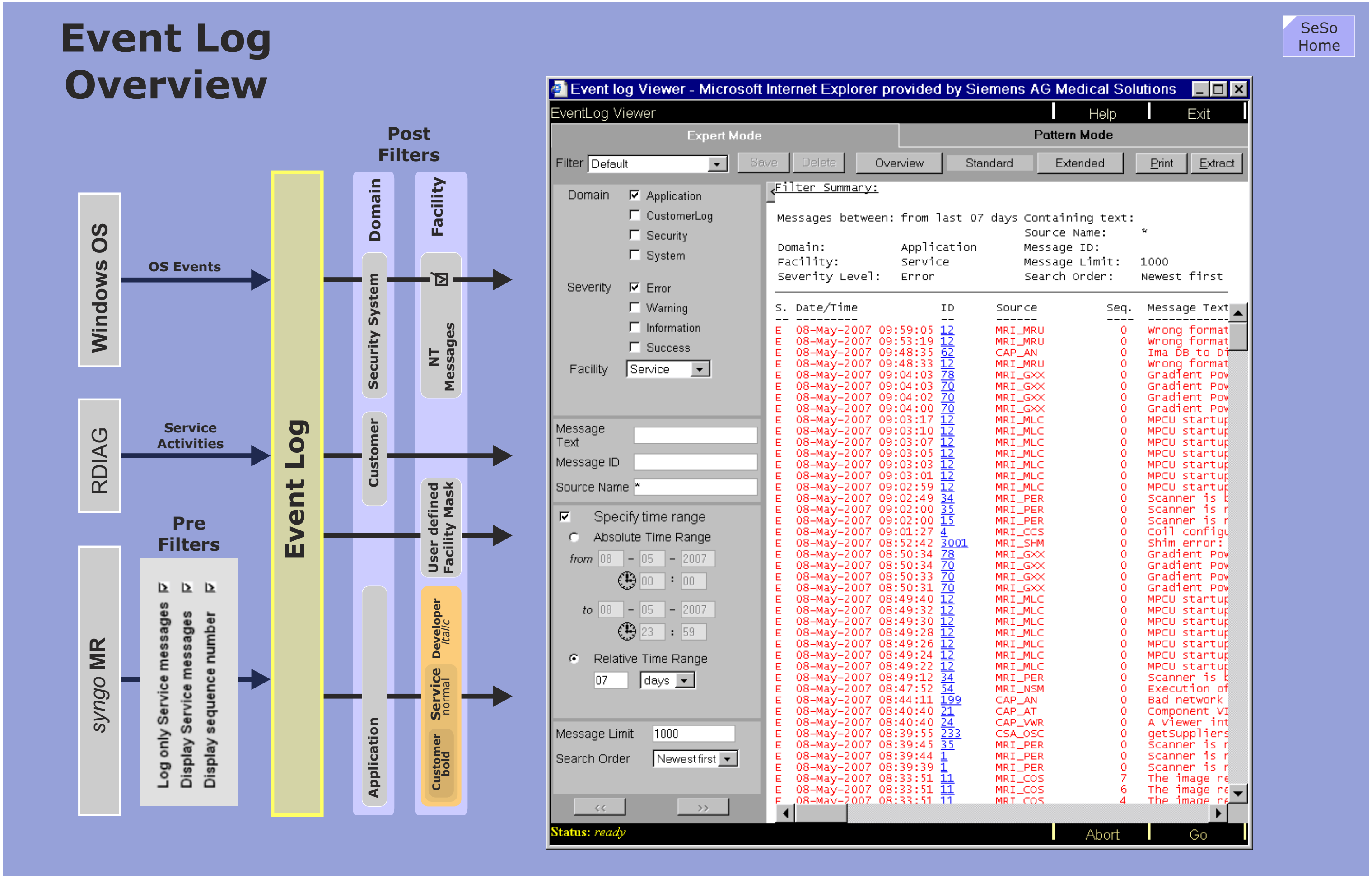
Domain

With the Domain filter only messages from the selected message source will be displayed.

Facility

For the display facility Service it depends on the service configuration parameter "Display Service Messages" whether service relevant Developer messages are displayed or not.

Figure 13 *Overview of Event Log*



SeSo Configuration

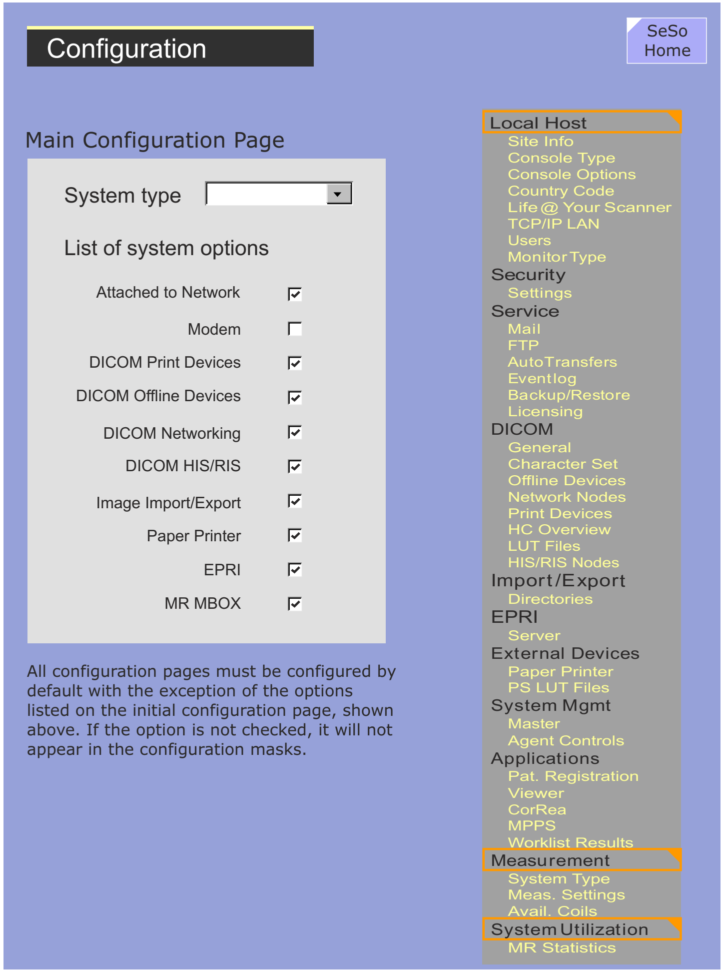
When entering the SeSo / Configuration page a list of system options is displayed with corresponding check boxes that can set if that option is to be configured. The list of options is shown on the configuration mask on the left side and the list of the corresponding configuration pages on the right, with colored boxes showing the options to the corresponding configuration page(s).

Even if no options would be checked all the default configuration pages will still be available and must be configured.

The following configuration masks will be discussed on the following pages:

- Local Host - TCP/IP LAN
- Measurement Settings
- System Utilization

Figure 14 *SeSo Configuration Tool*



Local Hosts - TCP/IP LAN

There are two networks implemented on the MR system:

- **internal**: connects the MRAWP Host to the MR scanner Control Unit and Imager.
- **External**: connects the MRAWP Host to the MRWP Host and customer LAN

Internal Network

The network adapter used for the internal network has a default IP address range of 192.168.2.x. The IP addresses and net masks for the AMC (MPCU) and for the Imager are automatically created from the NIC2 address and loaded from the Host during the scanner boot:

- 192.168.2.1 - Host,
- 192.168.2.2 - MPCU
- 192.168.2.3 - Imager.

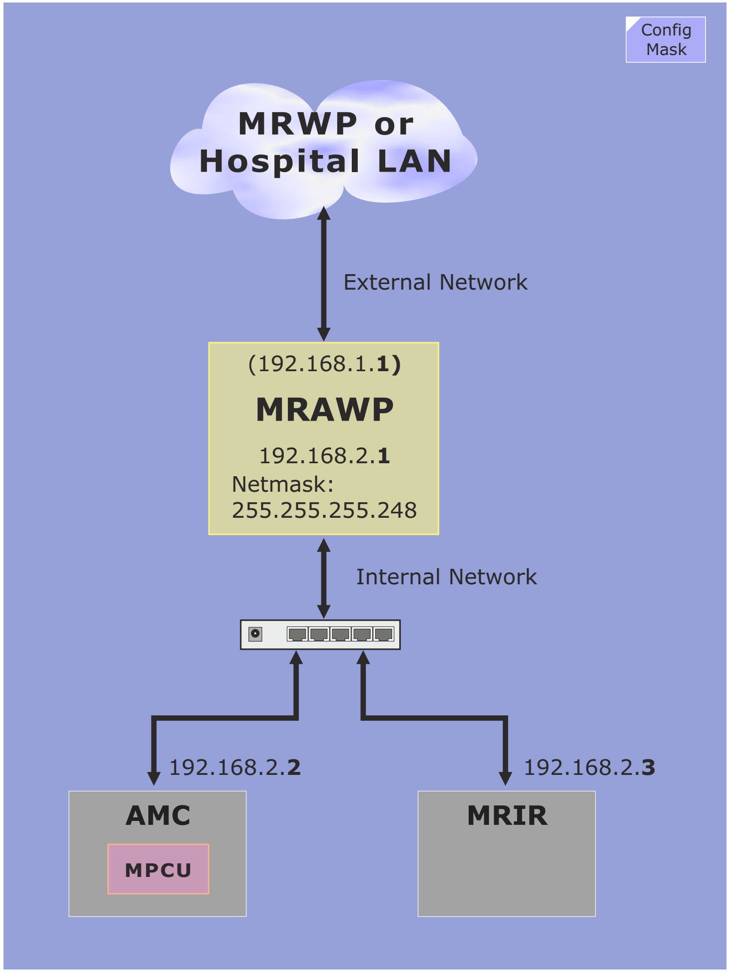
External Network

The network adapter used for the external LAN (connection to the customers LAN and/or the MRWP) has NO default. Its IP address must be configured.

IP Conflicts

In some cases the customer's LAN will be using the same address as the default IP address for the internal LAN, in which case the internal LAN address must be changed to avoid conflicts.

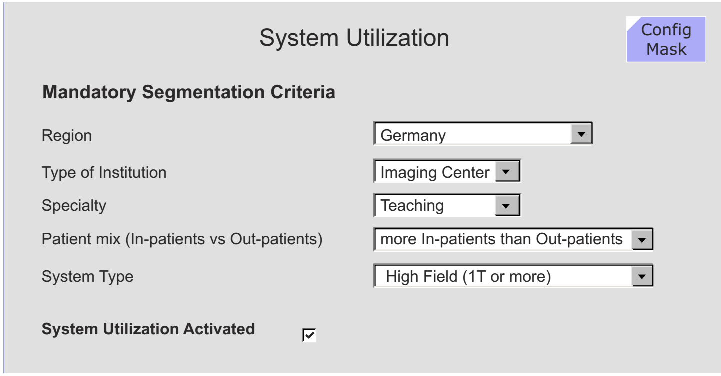
Figure 15 *Host Network Topology*



System Utilization

In the mask MrStatistic you set up the region, the type of institution and some more criteria and you activate the utilization with the check box System Utilization Activated.

Figure 16 *System Utilization*



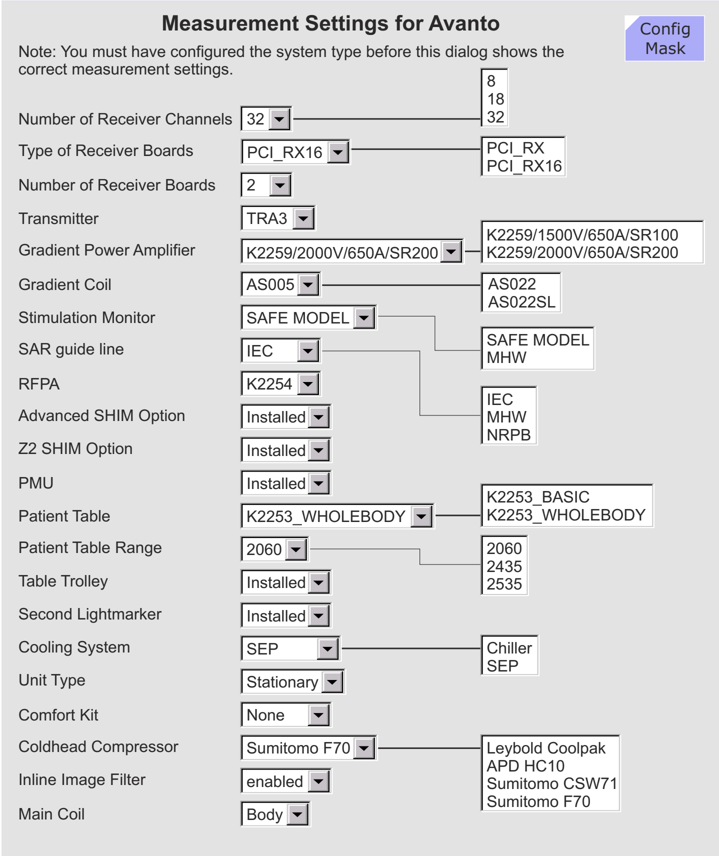
Measurement Settings

More accurately this page contains the settings for the scanner specific hardware configuration, i.e., the options which have been installed.

Also found on this page is the selection of SAR and STIMO monitor guide lines, usually country specific.

An additional page (not shown) is for selecting the coils which are on site. Only selected coils will show up in the list in the QA platform.

Figure 17 *Measurement Settings*



Backup & Restore

These functions allow scanner and site specific data, user protocols and service reports to be archived (backup) to CD media for restoring when the software needs to be reinstalled or if new software versions are installed.

Backup

There are several predefined backup packages that can be selected, each allowing the archiving of all or just a particular set of data. The only one used is the Master Backup which includes everything that can be backed up.

After inserting a medical-grade CD into the S drive (upper most drive), choosing the drive and backup package the GO button starts the backup. The program displays the backup progress textually in the SeSo window. and when finished displays a READY message in the status line. The backup file copied to the CD has a naming convention <name of package>-<date>-<time>.ar

Example:

Numaris4-10-02-2004-10-11-37.ar.

NOTE	Use only CD-R 's with medical grade, e.g. Siemens Medical CD-R 80 or TDK Medical CD-R.

Restore

When necessary, a restore of a backup archive is made using the Restore command. The backup CD is inserted into drive R. When the CD is loaded a list of the backup file(s) can be selected in the Archives pull-down menu. Select the desired archive and press the GO button. As with the backup procedure the progress will be given in the SeSo window and a READY message on the status line when finished.

Backup Packages

There are a number of predefined packages in the backup which allow archiving only certain items.

For information on what each package includes and which packages should be used refer to the service procedures and online help.

Master-Backup

Starting with VB13A a Master-Backup package was introduced which includes EVERYTHING (except HIPAA)!!! Imagine that.

Software Installation

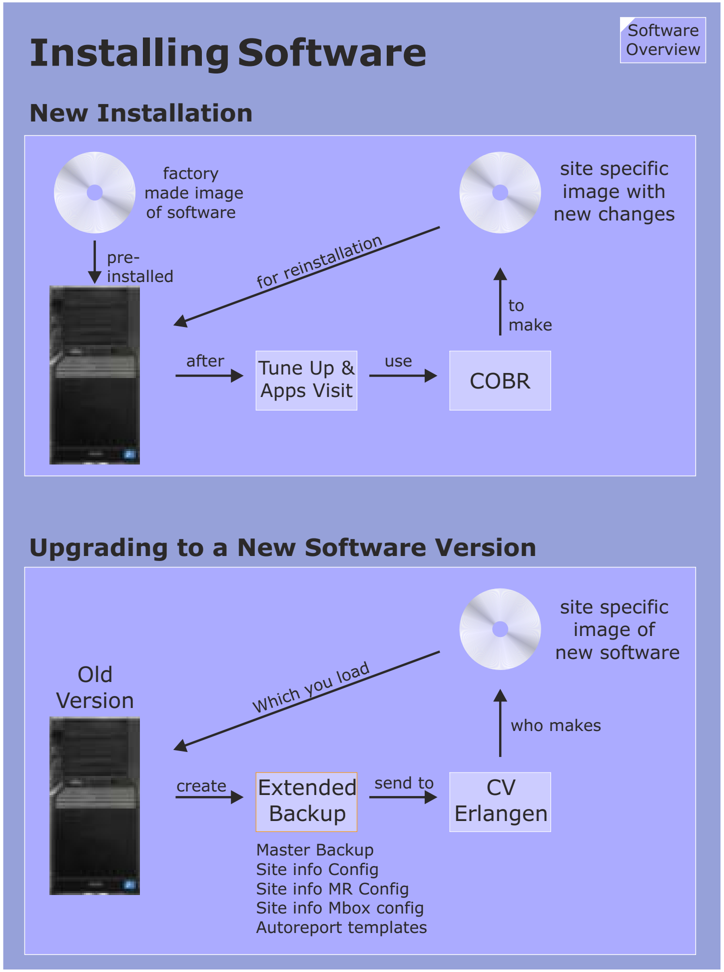
It is difficult to offer any wisdom on this subject. We all know it is a thankless job one has to do. To ease the pain, dwell on this: you are a highly skilled and extremely well paid professional.

Ok, here's our advice:

NOTE Refer to the software installation procedure in the Installation Software document for the corresponding software version.

PS: today's USB drives are capable of holding very LARGE volumes of data, relatively CHEAP and MUCH faster than DVDs. Think about that.

Figure 18 *Software Installation Scenarios*



Section

3

Host / Imager

Introduction

The Host of the MRAWP (MR Acquisition Work Place) interfaces to the MR scanner via the MPCU which also acts as the main controlling unit for the scanner hardware. The MPCU is located in the Advanced Measurement Control (AMC).

Although the MRAWP and Imager components are individual components they have been combined here in Part 4 since they work very close together.

In addition to the **MRAWP** is the optional MR work place console (**MRWP**) for post-processing of images. Based on the same host as the MRAWP its differs in hardware and software configuration.

MRAWP Host

The major tasks of the MRAWP host are:

- User Interface (syngo)
- take sequence measurement parameters from user and pass these on to the Measurement Control (AMC)
- image post-processing and image display functionalities
- archiving (mass storage, filming)

The MRAWP connects to the MR system over an ethernet LAN. This network connection is referred to as the "internal network".

MRWP Host

The MR Work Place (MRWP) is an option for

- image viewing
- post processing
- archiving images

The MRWP host connects to the MRAWP host over an additional ethernet switch, delivered with the MRWP option, and is required to decouple the large volume of image data transfers from the customer's LAN. This network connection will be referred to as the "external network".

The configuration of the MRWP host computer is much the same as the MRAWP host with the following exceptions:

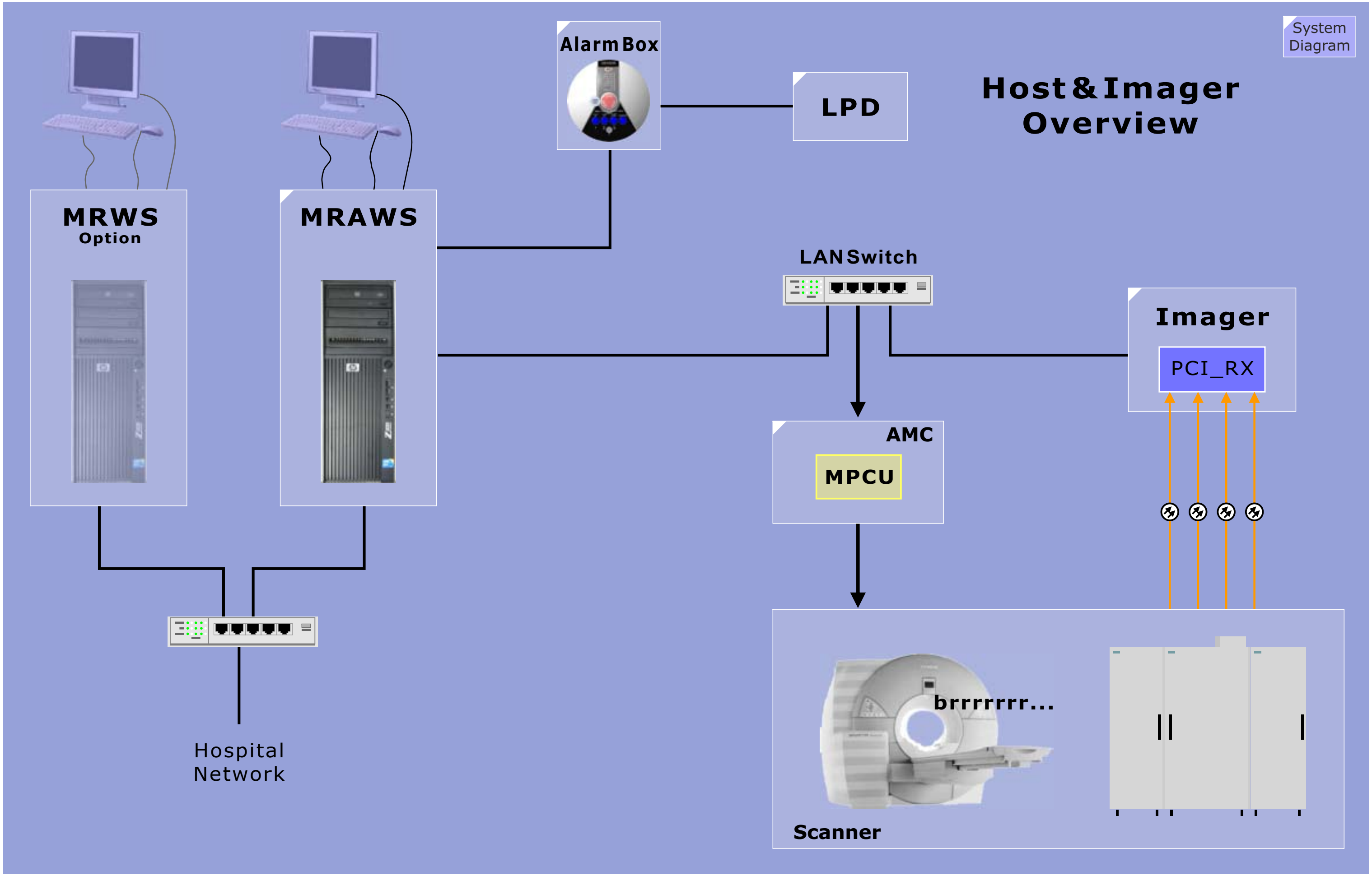
- NO hard drive pixel data (database and pixel data on one hard disk)
- Only 1 network interface - to communicate to the MRAWS
- NO MOXA interface card.

Imager (MRIR - MR Image Reconstruction)

The raw data coming from the AMC will be stored temporarily on one or more pixel disks.

The Ethernet connection provides the link from/to the MRAWP host for parameter downloading and uploading the image data for storage on the MRAWP pixel disk.

Figure 19 *Host / Imager Block Diagram*

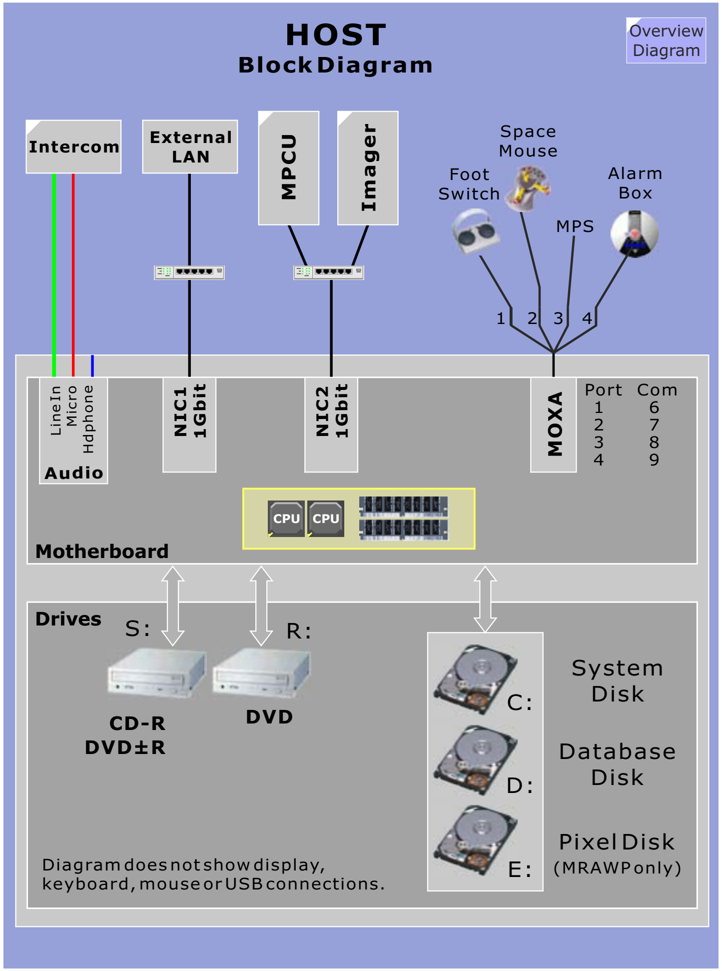


Host

Developments are rapid in the computer industry and so it is not surprising that the number of different Host models delivered with the Tim systems since its inception is considerable: 16 at the time of this update. And one thing is for sure: more are coming :-)

NOTE It has been decided to remove the Host list and refer the reader to the **Spare Parts Catalog** since all details needed will be find there (Host and Software dependencies, replacement models for EOS versions).

Figure 20 *Host*



Imager (MRIR)

Overview

The MR Imager (MRIR) is a 19" rack mounted industrial PC located in the ACC cabinet.

There are various versions of the Imager:

- Supermicro - Intel Xeon
- Step 2 Low End - AMD Opteron (VB13)
- Step 2 Standard - AMD Opteron (VB13)
- Step 3 - AMD Opteron for (VB15)
- Step 4 - McProX Intel Xeon (VB17)

Function

The demodulation and filtering of the incoming MR signals are performed on the **PCI_RX** boards. After initial processing, the "raw data" is temporarily stored on hard drives.

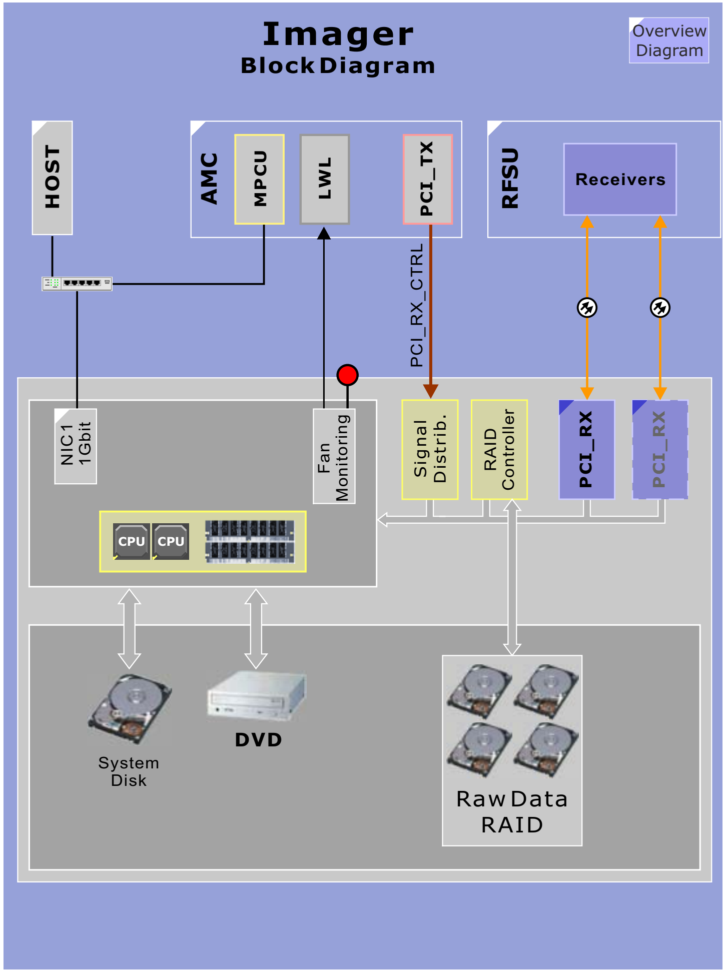
After collection of all raw data the image calculated and sent to the Host.

The Imager is also able to perform a number of post-processing functions automatically, called Inline functions. Many are optional and will require licenses.

As of this update there are 10 versions of the Imager in circulation. Below is a list summarizing their differences in configurations.

NOTE	The reader is referred to the Spare Parts Catalog for information regarding versions and software dependencies.

Figure 21 *Imager*



Imager Configurations

	CPU	Memory	PCI Slots
MR 005 Supermicro	2x 32-bit Intel Xeon @ 3 GHz	3,5 GB	**Slot 1**: Adaptec Raid Controller **Slot 2-5**: PCI_RX (see description)
Step 2 / Low End	2x 64-bit AMD Opteron 2.2 GHz 2,6 GHz	8 GB or 16GB	same as above
Step 2 / Standard	2x 64-bit AMD Opteron 2.2 GHz 2,6 GHz	8 GB or 16GB	same as above
Step 2 High End	4x 64-bit AMD Opteron Dual Core @ 2.2 GHz	16 GB	same as above
Step 3 Standard	2x 64-bit AMD-Opteron Dual Core @2.4 GHz	8 GB or 16 GB	**Slot 2**: PCI_RX16 board number 1 **Slot 3**: PCI_RX16 board number 2 (optional) **Slot 6** - LSI SAS controller (see description)
Step 4 McProX	• **8 Channel Tim**: 1 Quad Intel Xeon 2.8GHz, 8/16GB RAM • **18 Channel Tim**: 2 Quad Intel Xeon 2.3GHz, 8/16GB RAM • **32 Channel Tim**: 2 Quad Intel Xeon 2.8GHz, 16/32GB RAM		**Slot 2**: PCI_RX16_8 **Slot 2**: PCI_RX16_16 **Slot 3**: PCI_RX16_8 **Slot 2**: PCI_RX16_16 **Slot 3**: PCI_RX16_16

The amount of RAM depends on the application packages and upgrades to I- or T-Class. See the CBDOC/Installation/Options list for more information.

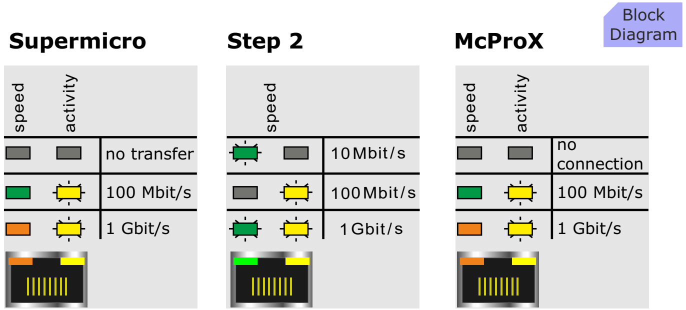
The Signal Distributor is always in slot 7 for all Imagers.

Buttons

The Imager has TWO LEDs and ONE button:

LED / Button	
RED	An LED found **only** on the Supermicro version and indicates a FAN or temperature error
YELLOW	A Reset BUTTON. When pressed, will reboot the Imager
GREEN	An LED indicating that power is available

Figure 22 *NIC LEDs*



PCI_RX Boards

The main task of the PCI_RX boards is to demodulate and to filter the acquired digital MR signals coming from the receiver boards of the RFSU. Once processed the resulting "raw data" is forwarded to the raw-data hard drives for temporary storage.

The main components of the PCI_RX are:

- PCI Control and Interface
- Receiver Interface with high speed FOC links,
- MOFIs for demodulation and filtering of four receive channels each,
- PCI_TX Interface to control the PCI_RX while running a sequence
- Echo RAM Buffer to store MR echo signals

There are three versions of this board, the main differences being the maximum number of RF channels it can process:

- PCI_RX (8 channel)
- PCI_RX16-8 (8 channel)
- PCI_RX16-16 (16 channel)

MRIR Configurations

The following table gives an overview of the possible MRIR configurations:

Tim Configuration	PCI_RX	PCI_RX16
[32 x 8] (Basic)	1 (slot 2)	1 PCI_RX16-8 (slot 2)
[76 x 18] (option)	3 (slots 2, 3, 4)	1 PCI_RX16-16 (slot 2) 1 PCI_RX16-8 (slot 3)
[76 x 32] (option)	4 (slots 2, 3, 4, 5)	2 PCI_R16-16 (slots 2,3)

Figure 23 *PCI_RX Overview*

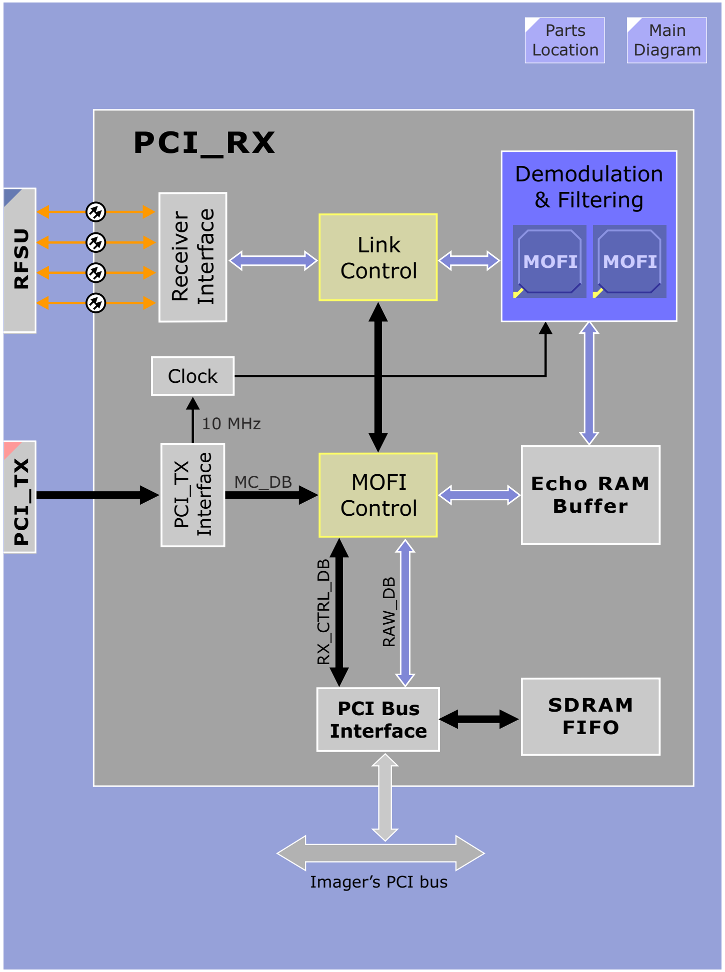


Figure 24 *PCI_RX Board Types*

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Section

4 Control

Introduction

Its Role

The Advanced Measurement Control (AMC) is the name given the component group responsible for exercising system and sequence control. The AMC has two major tasks:

Sequence Control

It is responsible for generating the gradient, RF and receive data readout events (including appropriate corrections to these pulses for the compensation of system and site specific tolerances and inaccuracies) as well as all sequence timing signals required to generate and acquire image data in a slice or 3D image volume. The resultant MR echoes are also sampled under control of the AMC and processed by the image reconstruction components for computation of the final image.

Communications

As the system's central intelligence unit, it has the further responsibility to provide a communication interface to the hardware periphery for supplying software, parameters, static control for those requiring them and a status/error feedback path.

Concept

The background concept of the sequence control implemented in the AMC is principally the same as that of the MMC (Modular Measurement Control) used in the non-Tim systems. In this concept, the sequences (C++ programs) run in real-time on the MPCU (**M**easurement, **P**hysiological & **C**ommunication **U**nit, the controller part of the AMC) which then feeds the DSPs of the sequence control components (PCI_TX, PCI_MON) with the sequence-specific tasks necessary to create the RF pulses, gradient pulses, and sequence timing signals, including compensation. The modulation of the RF pulses and demodulation of the MR echo pulses is also performed digitally following the example of the proven methods used in the previous system control unit. With the improvement in performance of the latest DSP components it has been possible to integrate the AMC components to just 4 boards allowing for a very compact design.

The AMC functional description has been divided into two parts:

- **Functional** - describes in details the functions performed by the AMC components.
- **Hardware** - describes the individual hardware components and their tasks.

Functional

In this section a description of the AMC's functionality will be presented. The Advanced Measurement Control responsibilities can be grouped into the following tasks:

- Scanner Software Download
- Sequence Control
- Supervision and Error Handling
- System Standby

Scanner Software Download

The peripheral hardware units of the scanner sub-systems, such as the Gradient amplifier, RF System, Patient Table, etc., provide necessary hardware control functions and monitoring. The programs for these units are stored in either in PROMs, EEPROMs or Flash EPROMS or are downloaded into RAM.

At power on, scanner components requiring software will be downloaded or checked for proper software versions. Components having their programs (firmware) in non-volatile memory will be checked whether they are up-to-date and if not, reloaded with actual versions. This task is accomplished by the MPCU. The software modules for the scanner hardware are physically located on the Host system disk. This process is described below and shown in Figure 25.

MPCU Boot Procedure

Power On Self Test (POST)

At power on, the MPCU performs an initialization and self test of its on-board circuitry. During this test routine, the BIOS writes progress codes, also known as POST codes, to LEDS connected on the parallel port (X26 on the AMC backplane). The LEDs display these codes in hex format. The POST Code description is found at the end of this section.

Operating System Load

Since the MPCU does not have its own hard drive, it has to load its operating system and run-time software from the Host.

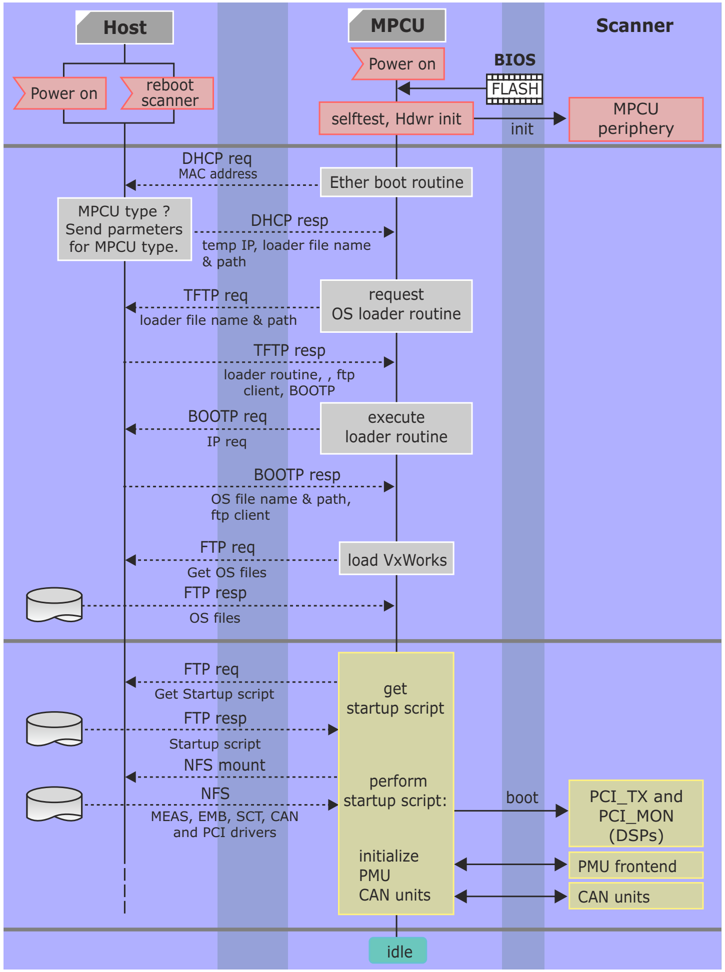
After the MPCU finishes performing the POST, it initializes the other AMC hardware components by applying a RESET signal. It then and jumps into a Ethernet boot loader routine which has the task to acquire an IP address from the Host to begin the LAN communication. The DHCP protocol is used for this.

A DHCP request is sent to the Host to request an IP address as well as the name and location of the OS-loader program file. The Host evaluates the MAC address since this reveals which MPCU board in installed. The Host then makes a DHCP reply with an IP address and the name and location of the proper OS-loader program.

Using the TFTP protocol the MPCU sends a request to the Host for the OS-loader program file. The Host also sends an FTP client program and BOOTP protocol routine needed for the next steps. Once received, the MPCU executes the OS loader routine.

The OS-loader issues a BOOTP request for an IP address (the first was only temporary) and the name and location of the OS files. These are sent back from the Host. The MPCU then uses the FTP protocol to retrieve the OS files from the Host.

Figure 25 *MPCU Software Download*



Start-up Script

Once the OS has been loaded the MPCU retrieves and executes a startup script from the Host which initializes the AMC components (i.e. DSPs and CAN units) and downloads them with the runtime software (loadware) programs retrieved from the Host.

Messages generated during the download will be logged into the log file **C:\Medcom\log\mpcu_startup.log**. To fully interpret this file requires detailed knowledge, but it could be helpful for technical support personnel if the problem needs to be escalated. This file will be overwritten by the start of the start-up scrip (e.g. with "Reboot Scanner").

For detailed messages of the MPCU activities another trace can be started with System/Run -> StartMPCUTrace. Messages will be logged into **C:\Medcom\log\MPCUTrace.log**.

Loadware

Once the MPCU has booted, the Host queries each component and delivers new loadware if necessary.

The PMU and CAN units also require LW. This will initially be loaded and stored into EEPROMs at the factory or by a software update. Afterwards the version will be only be checked for version. A unit will only be downloaded if the version is not correct.

Parameters

For most units parameters required for measurements will be supplied.

PALI Function Test

To test the PALI hard- and software a special PALI test sequence will be run during the scanner start up. This sequence is given parameters with very low SAR limits so that when the RF is applied it will exceed the limit and the PALI will cause a sequence abort. If an abort occurs, it signifies that the PALI is working.

Sequence Control

The sequence control tasks can be summarized as follows:

- RF Control
- RF Safety WatchDog (RFSWD)
- Gradient Control
- Gradient Safety WatchDog (GSWD)
- System Compensations
- Dynamic Control Signals

The sequence file is a compiled C-program which is loaded into the MPCU memory. In preparation for the measurement the MPCU first checks for system readiness. If everything is ok, the SCT (Sequence Control Task) will initiate the start of the sequence and begins feeding the sequence information to the DSPs. During the measurement the MPCU surveys for any error or status change from the AMC or periphery hardware components, and in case of any errors the sequence can be stopped and the operator informed.

RF Control

As the sequence progresses, the MPCU feeds the TX_DSP on the PCI_TX board responsible for the generation of RF-pulses with the corresponding requests and the RF pulse amplitudes are generated (calculated) in real-time. The pulse generation must also include system specific corrections and compensations such as correction of RFPA non-linearities and B_0 field correction.

Dynamic timing signals must also be provided for RF components RFPA (unblanking), RFIS (coil detuning), RCCS (receive matrix switching), BCCS (T/R switch) to name a few. These sequence timing signals are generated by the PCI_TX DSPs on requests from the MPCU.

RF Safety Watchdog (RFSWD)

The **RF Safety WatchDog (RFSWD)** - also called PALI: power absorption limiter - measures and limits the RF energy being irradiated into the patient. The applied RF energy causes warming of the patient both locally and globally, that is, warming in the direct vicinity of the transmitting coil and via blood circulatory a global warming of the body results. The RFSWD must quantify the amount of heat-causing energy being applied to the patient, calculate the distribution of these energies throughout the body and check irradiation limits, as defined by applicable regulatory guidelines, which may have been exceeded. If any limit is reached the RFSWD can disable the RF transmission.

The RFSWD is implemented as two independent processes:

Look-ahead Monitor

The first is a software look-ahead monitor running on the **Host** which evaluates the sequence and parameters (i.e. protocol) as they are selected and entered by the user. If the look-ahead monitor detects the protocol will cause excessive RF it issues warnings to the effect and suggests new parameters to bring the SAR under the limits. A sequence can only be loaded and started if it will not exceed the prescribed SAR limits.

There are two levels of SAR limits: normal mode (NM) and first level (FL). First level limits are higher than those of the normal mode and may only be selected under the explicit allowance of the user.

Online Monitor

The second process is realized in hardware and monitors the RF in real-time. The actual RF transmit pulses are sampled by directional couplers located in both the RF Power Amplifier and the TALES, quantified, and fed back to the RFSWD-DSP on the **PCI_MON** board (via Modulator and PCI_TX) for calculation. The online RFSWD keeps a running tabulation of the applied RF pulses and if limits are exceeded before the conclusion of the measurement, the sequence will be terminated.

Plausibility and Consistency Checks

After each sequence, the RFSWD makes a plausibility check of the measured RF. If the measured RF values are outside some range, the values are deemed non-realistic and an error will be generated. Also, the calculated SAR values performed by the On-line monitor are compared to the actual RF values measured during the sequence, if these two values deviate by some value an "inconsistency" error will occur. Both of these error are assuming there is anything wrong with the components used in measuring the RF.

Measurement of RF Power to Body Coil

Eight voltages from the RF System are read in at the Modulator (multiplexed) in 20 µs intervals and digitized:

- PALI_FORW_0 (Body coil system 1)
- PALI_REFL_0 (Body coil system 1)
- PALI_FORW_90 (Body coil system 2)
- PALI_REFL_90 (Body coil system 2)
- PALI_FORW_LOC (local coil)
- PALI_REFL_LOC (local coil)
- PALI_OFFSET

The digitized data are transferred to the PCI_MON via the PCI_TX.

The PALI_DSP uses the data to calculate the RF power deposition to the patient. Frequency dependencies of the TALES are corrected for by the DSP.

Gradient Control

The gradient pulses are generated in much the same way as those for the RF. As the sequence progresses the MPCU supplies the GC_DSP on the PCI_TX board with requests for pulse generation of the logical slice selection, read-out and phase encoding gradients. A rotation matrix is then sent so the GC_DSP can calculate the logical amplitudes (SS, RO, PE) into the physical of X, Y or Z. The DSP then makes corrections for the eddy-current, cross-term and B_0 compensations before sending the data to the gradient amplifier. The amplitude data is for each axis 20 bits wide and some additional timing and control signals are sent as well. There are more signals than pins in the cable to the gradient so the data has to be multiplexed.

Gradient Safety Watchdog (GSWD) -Stimulation Monitor

When applying Gradient pulses during an MR examination muscular stimulations of the patient can occur. The cause of these stimulations is the development of electrical fields within the patient’s nerve fibers which are induced by the dynamic magnetic field generated by the gradient coil. The magnitude of these induced electrical fields is, for any given sequence type, proportional to the change of the magnet field in time, expressed otherwise as dB/dt.

A stimulation occurs when a characteristic threshold of the electrical field is exceeded. The corresponding dB/dt value needed to exceed this limit depends on the patient’s anatomy and physiology, the geometrical and physical attributes of the gradient coil and the position of the patient within this coil.

dB/dt is determined by the amplitude and rise time of the gradient pulses. In actual imaging conditions, dB/dt is never constant, but is dependant on the sequence type and sequence parameters (e.g. slice thickness, FOV, Matrix size, TR, TE, number of slices, etc.). The stimulation thresholds are further influenced by the timely organization of the individual gradient pulses, the total number of pulses their repetition time and the coincidence of any or all three gradients at any one time.

The Gradient Safety WatchDog (GSWD), also called stimulation Monitor (STIMO), provides the safety against patient stimulation. The stimulations monitor (STIMO) is realized in three parts:

- a Look-ahead monitoring with a "SAFE Model"
- a Look-ahead monitoring using the legal dB/dt-Limits
- a run-time monitoring with a "SAFE Model"

Look-ahead Monitor

The look-ahead monitor is calculating the STIMO as the sequence parameters are being entered. If the chosen parameters will result in a stimulation a warning message is issued to the effect and eventually changes are suggested which will prevent stimulations.

SAFE - Stimulation Approximation by Filtering and Evaluation

In the SAFE Model, the physiological stimulation is approximated by filtering the differentiated gradient pulses. Each gradient pulse is differentiated and then filtered by applying at least two exponential functions using two time constants. The filtered signals are then added together using a weighting function and then compared to an established limit. The established limits have been derived empirically through studies done on real people (they are all still living). If these limits are exceeded, stimulations are to be expected.

Online Monitor

The actual value gradient currents are digitized on the D60 Service board in the GSSU and sent to the PCI_MON over a parallel cable connection between the D60 and the AMC backplane.

The STIMO_DSP on the PCI_MON calculates the actual gradient values and compares them to stimulation limits. If a limit is exceeded, the GPA will be disabled via a signal carried to the GPA over the same parallel cable.

System Compensations

Coil Tuning

All coils, including the body coil, designed for use on the Avanto and Espree systems are **no-tune coils**. The tuning adjustment is no longer performed.

Adjustments

Before a sequence measurement can begin there are some system and patient dependent adjustments which must be performed. These include:

- adjust frequency (Adj/Fre)
- adjust transmitter (Adj/Tra)
- adjust shim

All of these adjustments are in themselves sequences. The sequence is loaded into the MPCU and performed as any other sequence. The measured raw data will be transferred to the Imager (MRIR) where the evaluation is performed.

3D Shim

The 3D Shim procedure measures the magnetic field, determines the field in homogeneities and calculates the necessary corrections. The 1st order in homogeneities (linear terms) are compensated by driving an offset current through the gradient coils. For compensating the 2nd, high-order terms the Shim Array option consisting of 5 shim coil supplies is required. The 5 shim coils are always present and built into the gradient coil. If the shim option is not present, the 3D Shim will only apply the three linear gradient offsets.

Eddy Current Compensation

Eddy current compensation is performed digitally by the GC_DSP on the PCI_TX. The correction values are determined in a tune-up procedure. The correction also includes a B_0-component, which is implemented by changing the synthesizer frequency dynamically during the sequence.

Gradient Delay

The gradient delay compensation for the three axis is also performed by the GC_DSP on the PCI_TX. The necessary time parameters are determined in the tune-up procedure.

Dynamic Control Signals

Various dynamic control signals required by several RF components and the gradient amplifier are generated by the GC_DSP on the PCI_TX board.

Supervision, Error Handling

During the sequence the MPCU supervises the AMC components assure the DSPs are happy or if the measurement has to be stopped in case of some functional or run-time error. There are two main events that can cause an abort of the sequence:

- input of an **error message** from a unit
- the **system state** changes to "not normal"

Error Messages can be generated by any of the units. If an error is detected, it will be classified and sent to the MPCU. Here, dependent on the context, that means, if a sequence is running or not, the MPCU will decide what to do. The following **error classes** are established:

- Warning
- Error and
- Alarm

In all cases the operator will be informed and there will be a new entry in the **NUMARIS Eventlog**. A running sequence will be stopped only in case there is an "Error" or an "Alarm" classification. The SCT will stop feeding the DSPs.

In addition to the error messages, there is also the **System State**. For each of the CAN units there can be up to 32 bit of status information available, giving detailed unit status.

If a status bit changes, e.g. due to an over temperature in the gradient coil or a malfunction in the chiller, the MPCU will be informed automatically via the CAN bus. This new state will be compared with the predefined patterns for each of the units, representing the normal working state. This definition is stored in the status file of NUMARIS and can not be changed by the operator. If the comparison shows a discrepancy an error will be created.

There are some cases, where the peripheral unit already knows, that the status change will lead to an error condition. In such a case, the unit itself already will create an error message. So it can happen, that an error condition results in **two error messages** sent to NUMARIS!

CAN Network

The communications network over which the supervision and error handling takes places is a CAN (Controlled Area Network) bus consisting of a main CAN controller and several remote CAN units coming in two variations: CAN Modules and CAN SLIOs. The main difference between the two lies therein, that the modules have CPUs and the SLIOs do not.

System Standby Mode

System Power ON_OFF Control

The Host is able to put the system into standby by sending a signal to the appropriate relay in the Line Power Distribution via the serial connection to the Alarm Box. In the Standby-mode all system components are switched off, with the exception of the MRAWP and MRWP hosts.

Hardware

The AMC is located the ACC cabinet and consists, from right to left, the following components:

- **Power Supply** - supplies the AMC components with all necessary voltages.
- **MPCU** - a Pentium 3 based single-board computer solution running on the real-time operating system VxWorks
- **PCI_CAN** - an OEM board consisting of three (3) CAN controllers: CANopen mute (CAN0), CANopen active (CAN1) and CAN proprietary (CAN2)
- **PCI_TX** is responsible for the RF and gradient pulse generation.
- **PCI_MON** - responsible for RFSWD and GSWD monitoring
- **LWL_INT** - responsible for converting TTL control signals into fiber optic signals, monitoring of AMC operating voltages.
- **Backplane** - provides several busses for communication between AMC components and distributes voltages from the Power Supply

Communication between AMC components is made over a compact-PCI Bus (cPCI). With the exception of the mechanical portion the cPCI bus has the same bus architecture as the typical PCI Bus components found in PCs.

For the display of the external main connections see the System Block Diagram.

Figure 26 *AMC Layout*

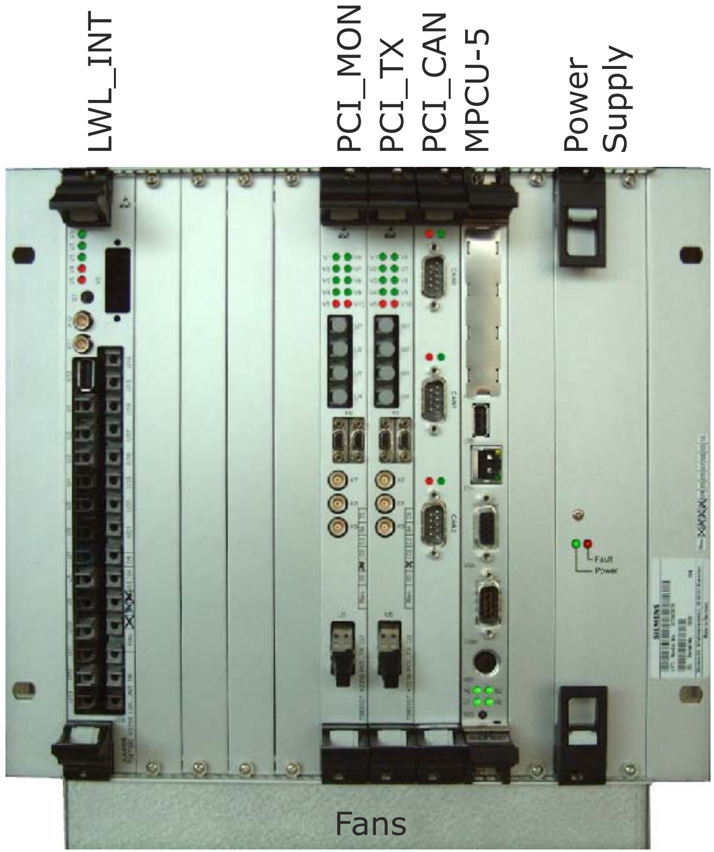
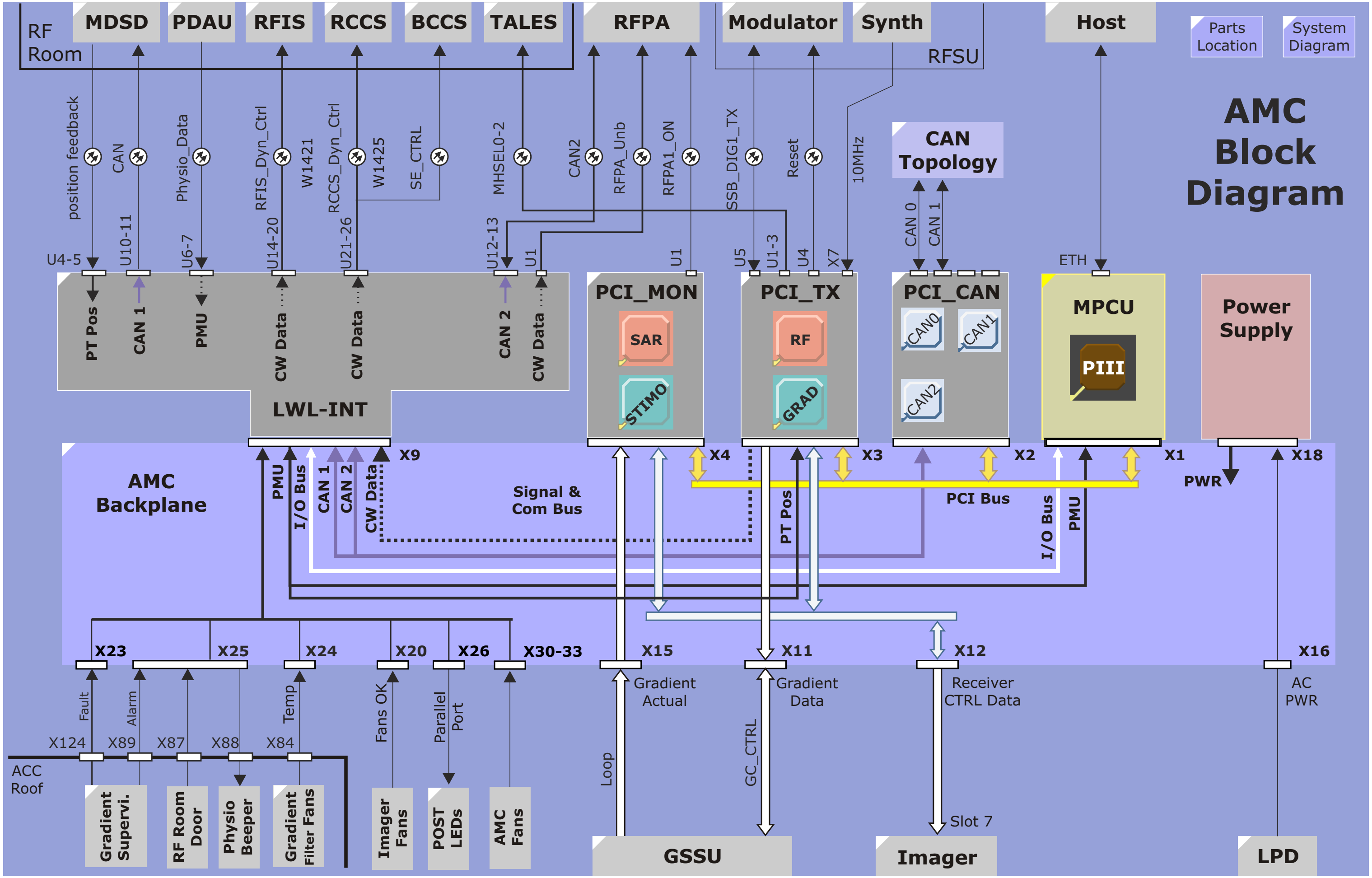


Figure 27 *AMC Block Diagram*



MPCU

Figure 28 *MPCU_5 Layout*

Overview

The MPCU is an single-board industrial computer, model EUROCOM 248, manufactured by ELTEC Electronik AG. The main features:

- cPCI plug-in board
- Intel PIII-Tualatin, 1,26 GHz, 512K L2-Cache
- 256MByte RAM
- PCI-BUS: 33MHz, 32 Bit
- Ethernet 100Mbit/1000Mbit, 2 serial, 1 Parallel, 1 USB, 1 PMC-Slot
- VxWorks real-time operating system (OS)

The EUROCOM 248 is an Intel Pentium III single-board computer with a CompactPCI interface, optimized for real-time applications.

The board is based on the Intel 815 PCI chip set, following Intel’s “Universal Motherboard” design guidelines. As it is part of the “embedded product line”, availability for longer periods than what is common in the PC market is guaranteed.

It includes all necessary peripheral device interfaces, including a **RESET** button.

Memory Configuration

The 64-bit wide memory allows configurations from 64 MBytes to 512 MBytes using one SODIMM with 133 MHz SDRAM. Memory size is detected automatically. The second-level cache is located on the CPU chip. There is a nonvolatile memory with 2 kBytes capacity on the board.

Firmware

The BIOS (General Software) is stored in a Boot-Block structured Flash-EPROM which enables easy BIOS updates. Boot from floppy, IDE hard disk, CD-ROM, CompactFlash is supported. A net boot is supplied in the same Flash Prom. See Scanner Download procedure

A service terminal can be connected to the serial port setup of boot parameters in the BIOS (setup: 9600 Baud, 8N1).

Function

The MPCU has many tasks to perform, the majority of which can be placed into two categories:

- Sequence Execution
- Communication

Both of these tasks are purely software functions and tested, in part at least, by the service test tools. The Hardware functionalities are tested or checked by the MPCU itself during its Power On Self Test (POST) routine. There is a POST code that indicates at what point an internal failure occurred.

The MPCU is an industrial single-board controller based on an Intel P3 chip set. The block diagram is given for informational purposes only.

The best source of information for this board is the CS Knowledge Database.

LEDs

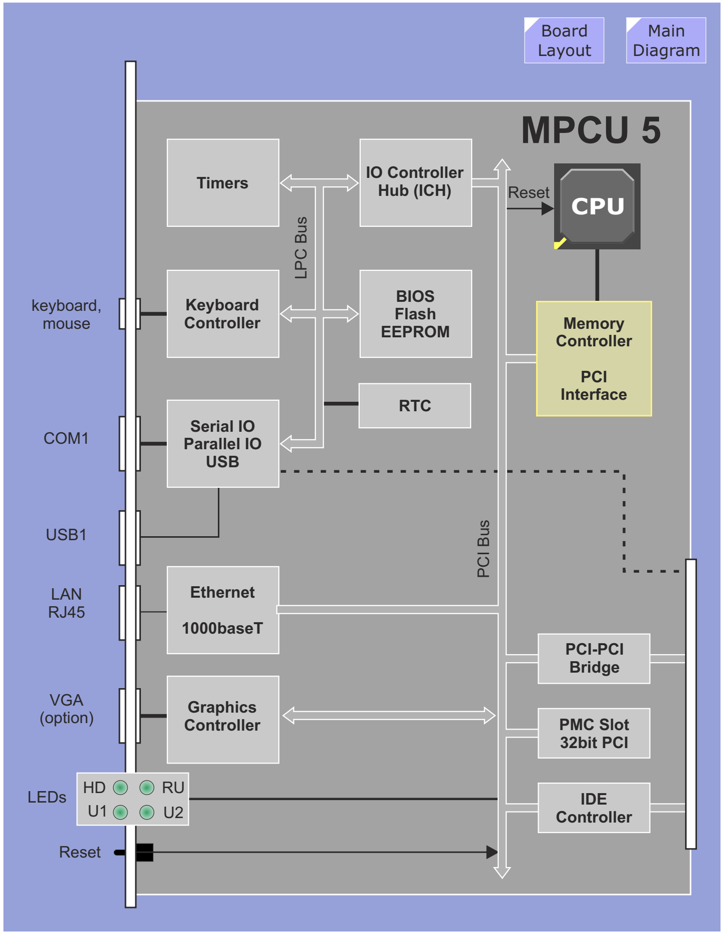
The MPCU_5 provides 4 LEDs:

- HD : hard drive activity (not used)
- RU : CPU Run (OK when blinking)
- U1, U2 : user programmable (not used)

Buttons

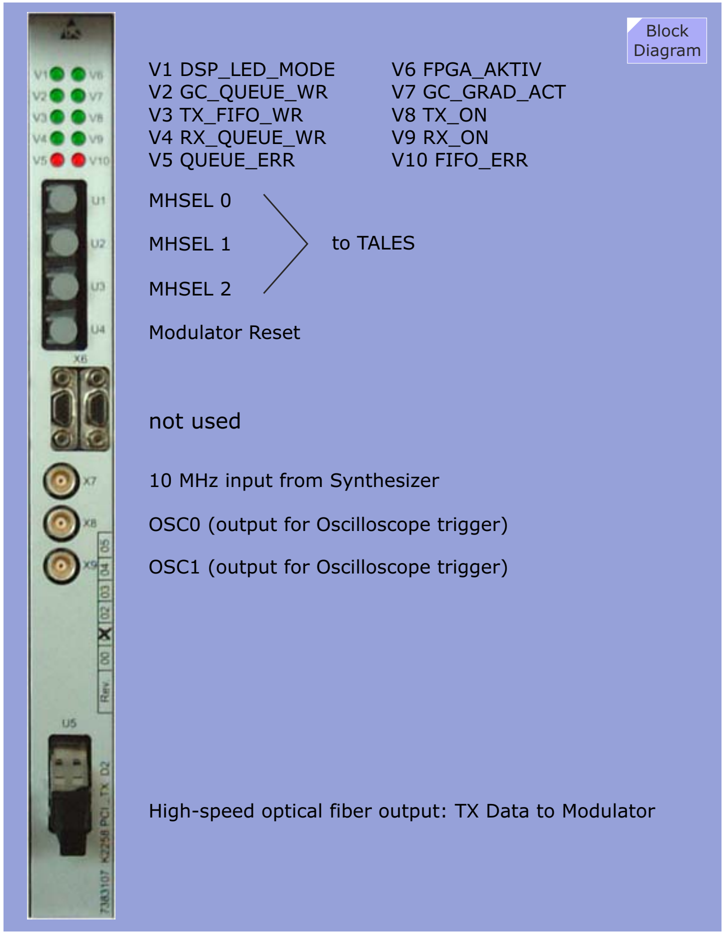
Yes, there is one. The **RESET** button. Pressing it will result in a re-boot of the scanner. It has the same effect as "Reboot Scanner" under the System / Control > Scanner menu card of the Host software.

Figure 29 *MPCU_5 Block Diagram*



PCI_TX

Figure 30 *PCI_TX Layout*



Overview

Compact-PCI PC board for the generation of excitation RF pulses and gradient pulses.

- 2 SHARC Hammerhead DSPs
- 2 Numeric Controlled Oscillators (NCO) - One for normal imaging, the other for spectroscopy frequencies.
- Full digital modulation
- interface to PCI_RX for transfer of receive control information, control signals, echo length, dwell time, measurement data header (MDH), NCO-Frequencies

Function

The following functions are performed in software on the DSPs:

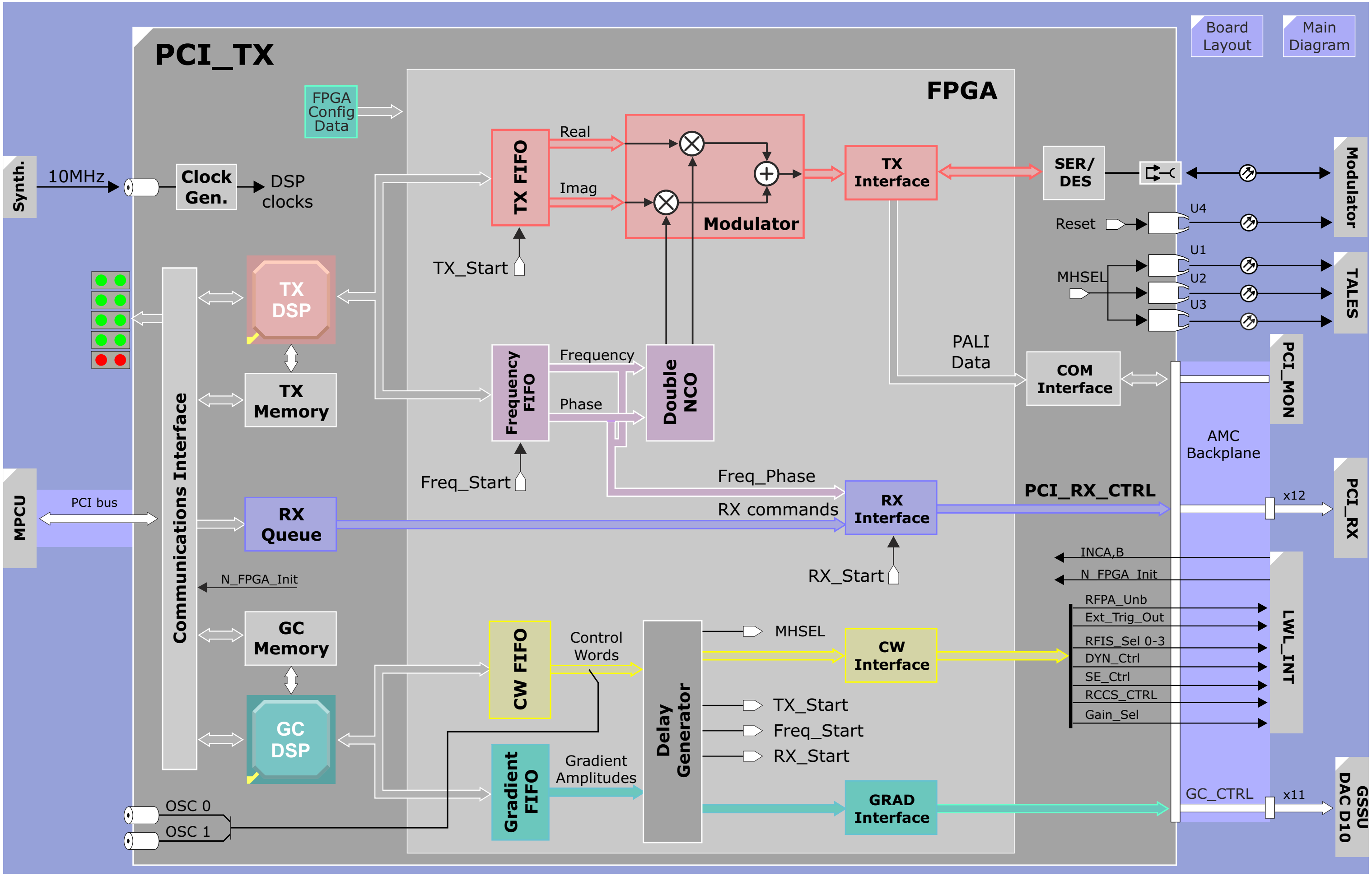
- Calculation of the RF pulse amplitudes
- Frequency dependent RFPA correction curve compensation in amplitude and phase
- Frequency dependent RFPA correction of Modulator tolerances (frequency dependencies of the 6 and 12 dB attenuators)
- Calculation of the gradient pulse amplitudes in the logical coordinate system
- Conversion of the gradient pulse amplitudes from logical to physical coordinate system (coordinate rotation operations)
- Eddy current compensation
- Cross term eddy compensation
- B_0 compensation

For the detailed description of the functions performed by the AMC components, refer to the Functional section above.

LEDs

The LED pattern changes between standby and sequence-running conditions! Also, the LED pattern may be different for different sequences.

Figure 31 *PCI_TX Block Diagram*



PCI_MON

Figure 32 *PCI_MON Layout*

Block Diagram

V1 DSP_LED_MODE
V2
V3
V4 GPA_ON
V5 STIMO_ERR
V6 FPGA_AKTIV
V7 RFPA1_ON
V8 RFPA2_ON
V9 Modulator_ON
V10 PALI_ERR

RFPA1_ON (DORA, PORA)

RFPA2_ON (CORA, MNO option)

10 MHz clock output (to EFI_DAS for Concerto, C!)

100kHz clock output (to EFI_DAS for Concerto, C!)

not used

not used

not used

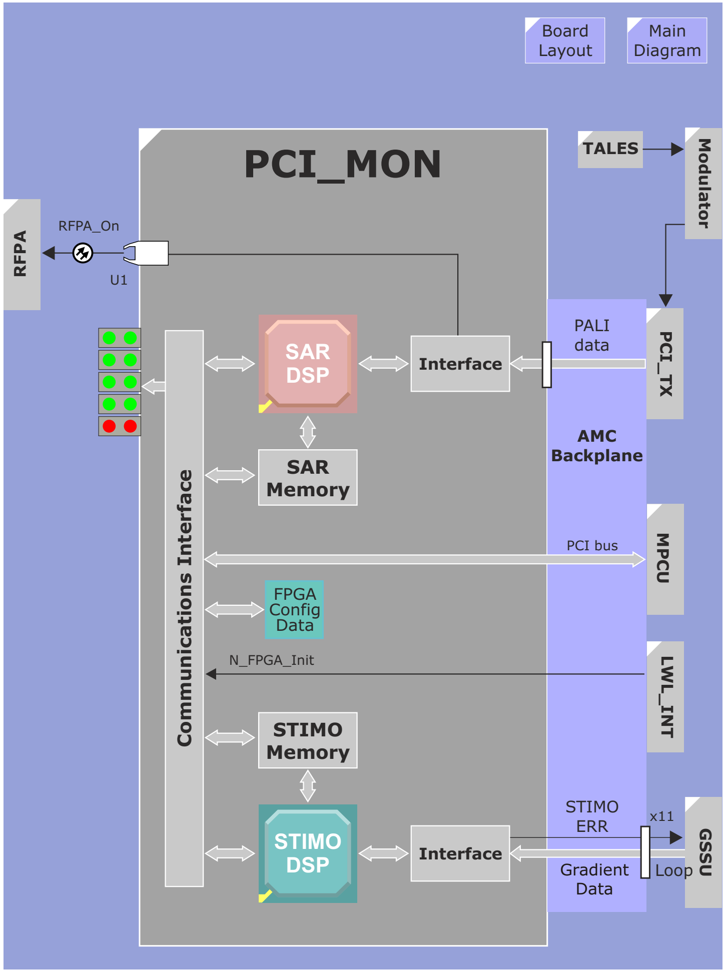
Overview

- Identical hardware as the PCI_TX
- FPGA programming determines the boards functionality
- Receives the digitized TALES values from the PCI_TX over the backplane required for the PALI monitoring
- A optical fiber output for disabling the RFPA in the event of a PALI error
- Receives the actual gradient pulse output values from the GPA (as measured by the CCU) via a cable connection used for the stimulation calculations. The GPA can also be disabled over the same connection
- The PCI_MON delivers a 10 MHz- and a 100kHz- clock to the optional EFI_DAS over optical fiber connections

LEDs

The LED pattern changes between standby and sequence-running conditions! Also, the LED pattern may be different for different sequences.

Figure 33 *PCI_MON Block Diagram*



Function

The following functions are performed in software on the DSPs:

- RF Safety Watchdog (PALI-Algorithm)
- Gradient Safety Watchdog (stimulation monitor STIMO Algorithm and/or optional EFI-Algorithm)

PCI_CAN

Figure 34 *PCI_CAN Front View*

Block Diagram

CAN 0

Device	Node	Protocol	Speed
MSUP	1	CANopen Mute	250 kbit/s
Alarm Box	3		
PTAB	6		
MPS	8		
RFIS	9,10		
RCCS	11		

CAN 1

Device	Node	Protocol	Speed
GPA	2	CANopen Active	250 kbit/s
MDSD	4		
ACS	5		
SHIM	7		
LWL_INT	12		

CAN 2 (over AMC backplane)

Device	Node	Protocol	Speed
RFPA	8	CANproprietary	100 kbit/s

Connection is over backplane to LWL_INT!

Overview

The PCI_CAN is an OEM board implementing the non-proprietary CAN protocol. There are three CANOpen component types:

CANopen SLIO	CANopen Module	CANopen Master
• 8 bit controller • ports definable as inputs or outputs • simple slave implementations	• 8 and 16 Bit versions • programmable (CPU) • packaged as a plug-in module • complex slave implementations	• 32 bit (JANZ) • CANopen master implementation The PCI_CAN is a Master.

CAN Bus Types

Three separate CAN busses are required:

- CAN 0 - for the components inside the RF Room - is muted (put into standby) when scanning
- CAN 1 - for components outside the RF Room - remain active at all times
- CAN 2 - required by the RFPA (older CAN protocol) - is muted during scans

LEDs

Green	Red	Interpretation
ON	ON	Operational, not connected to Host
ON	OFF	Operational, connected to Host (**NORMAL**)
1 Hz	ON	Operational: need firmware download
OFF	2 Hz	FAULT: watchdog error
OFF	ON	FAULT: initialisation failed
---	1 Hz	FAULT: hardware failure
OFF	OFF	FAULT: in reset, no power, or defective

CANproprietary

The DORA RFPA uses the older CAN proprietary component and requires a separate CAN controller on the CAN 2 bus. Since the RFPA requires an optical fiber CAN connection, the CAN 2 bus is sent to the LWL_INT for conversion.

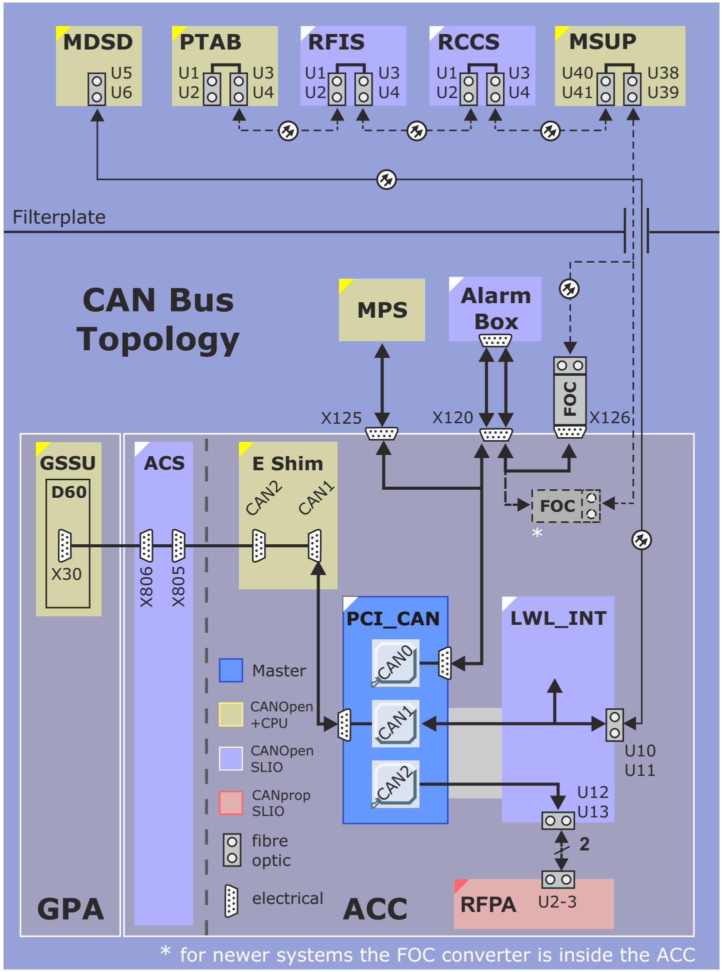
Summary of CAN Nodes

Device	**Node**	Bus	Protocol	Speed
MSUP	1	CAN0	CANopen Mute	250 kbit/s
Alarm Box	3			
PTAB	6			
MPS	8			
RFIS	9,10			
RCCS	11			
GPA	2	CAN1	CANopen Active	
MDSD	4			
ACS	5			
SHIM	7			
LWL_INT	12			
RFPA	8	CAN2	CANproprietary	100 kbit/s

CAN Configuration

All device specific parameters are stored in device configuration files (DCF). During the Bootup, the Configuration Manager (CANopen Master on PCI-CAN) scans the CAN busses for available nodes and configures the nodes automatically based on DCF.

Figure 35 *CAN Bus Topology*



LWL_INT

Overview

The LWL_INT is an interface board. The functions found on this board are:

- electrical/fiber optic conversion
- CANopen-SLIO monitoring of:
  - various fans
  - RF room door
  - contact monitoring and further Parallel-I/Os
- monitoring of the AMC and MRIR fans
- monitoring of the AMC power supplies
- a **RESET BUTTON** for manually resetting the AMC and Co.

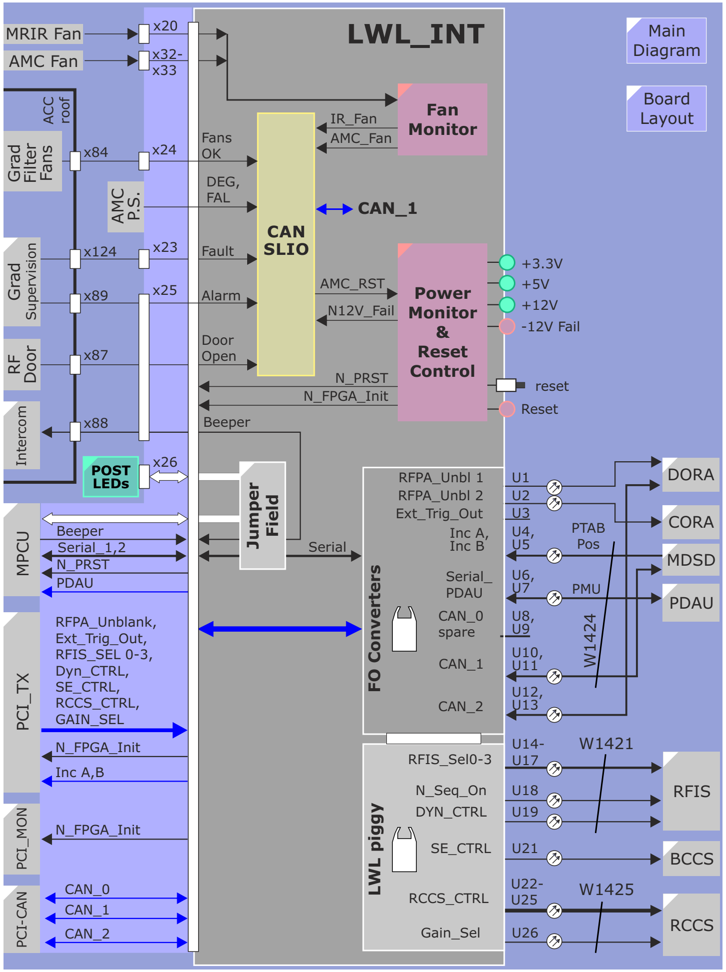
Function

CAN SLIO

The CAN SLIO supervises or supplies:

- RF room door contact (Door_Open)
- fan monitoring errors
- voltage monitoring errors
- reserved control signals and info-signals (triggers) for future use (available at X23, X24, X25)
- issuing of a general AMC Reset

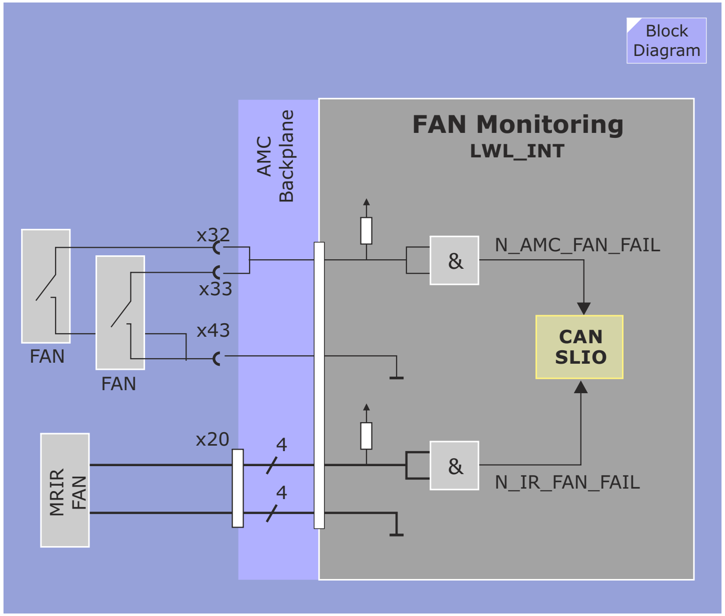
Figure 36 *LWL_INT Block Diagram*



Fan Monitoring

Adequate cooling of the AMC and Imager components is imperative to prevent overheating and eventual damage of the boards. A fan monitoring circuit has been implemented to assure the proper operation of the fan assemblies. The fans have electronic monitoring (shown as simple mechanical switches in Figure 37) which send back a signal indicating whether fan operation is ok. Should a fan fail it will result in an error signal to the MPCU via the CAN.

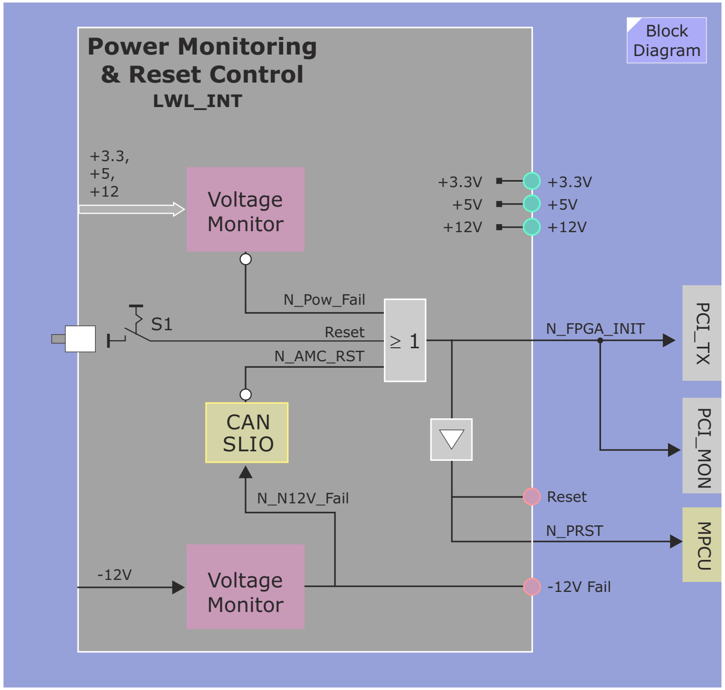
Figure 37 *Fan Monitoring Diagram*



Power Monitoring

The monitoring checks the +/- 5% limits. Any power failure will cause a reset of the AMC components. If this occurs during a measurement, the measurement will immediately be terminated.

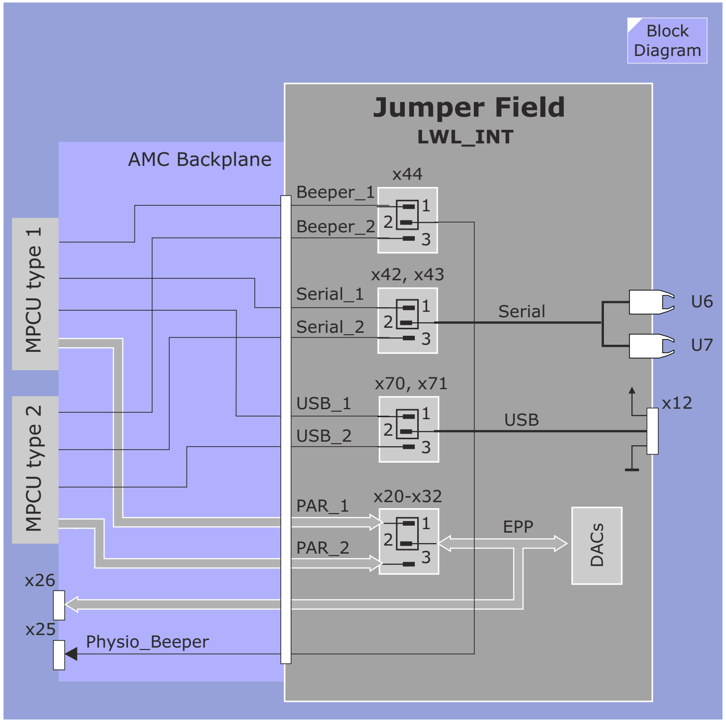
Figure 38 *Power Monitoring Diagram*



Jumpers

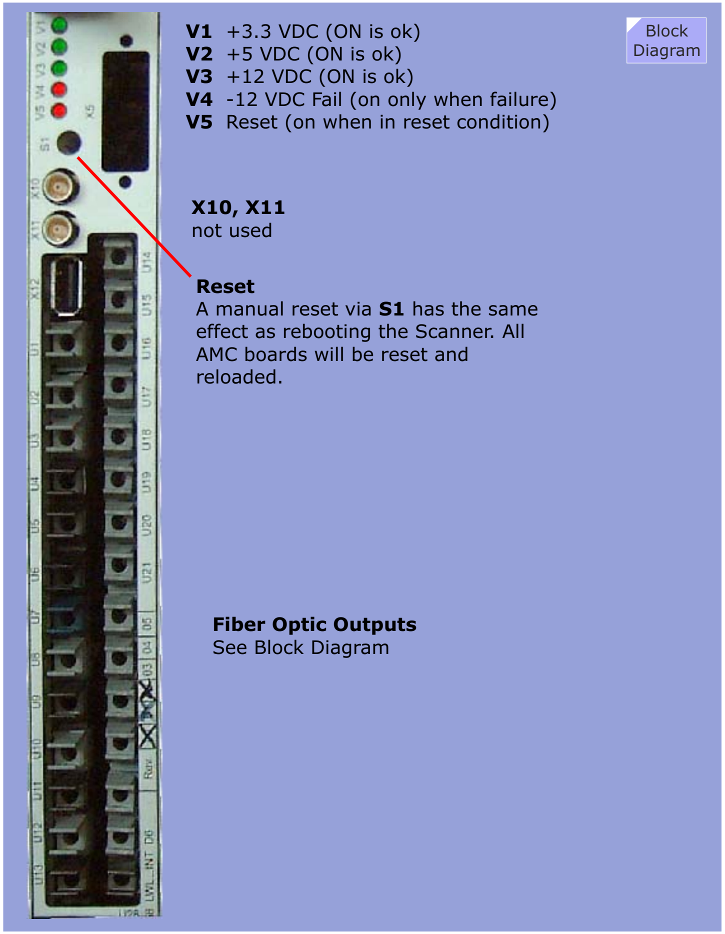
The jumper is intended to accommodate MPCUs from different manufactures.

Figure 39 *Jumper Field Diagram*



NOTE For the ELTEC MPCU, all jumpers will be set 1-2.

Figure 40 *LWL_INT Front View*



AMC Backplane

Overview

- 8 compact PCI slots
- 4 special-purpose busses
- provision for 230 VAC connection for a slot-type power supply
- connectors for distribution of control and data signals to the periphery
- plug-connections for cooling fans

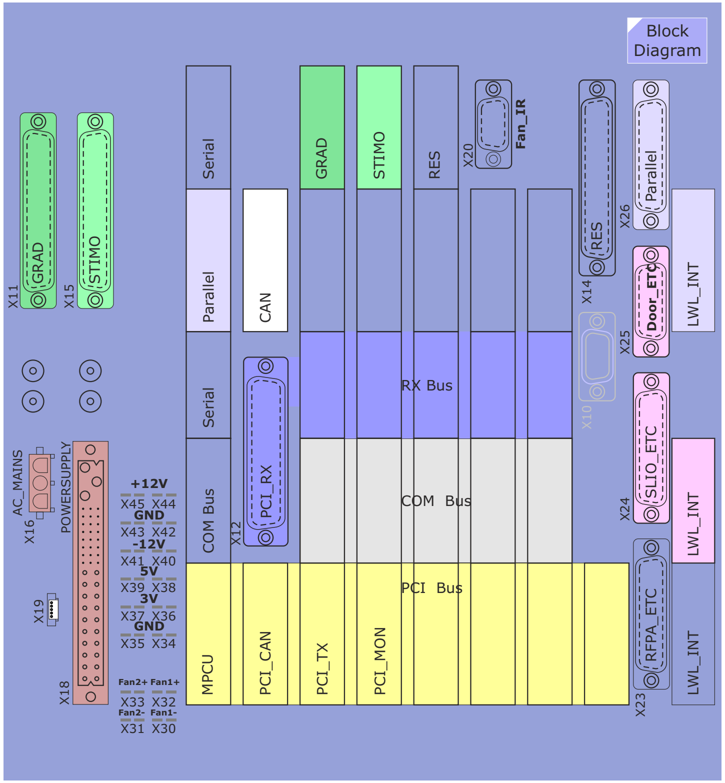
An overview of the AMC backplane contour shows the locations of the connectors. The pins are labeled on the board.

Bus System

- PCI-Bus: Serves mainly to provide communication between the MPCU and the other AMC components (PCI_CAN, PCI_TX and PCI_MON). This bus is industry normed.
- COM-Bus: A proprietary bus providing communication directly between the DSP-based boards.
- RX-Bus: provides a data highway between the DSPs within the AMC and the FPGA on the PCI_RX boards in the imager.
- Signal-Busses: individual signal busses connecting the AMC boards to the signal-distribution connectors.

Enough slots have been supplied to allow for future expansion.

Figure 41 *AMC Backplane Layout*



PCI_RX

See the description in the Host and Imager section.

MPCU POST Codes

Go back to MPCU Boot Procedure

Go back to LWL_INT Block Diagram

Go back to MPCU description

Mnemonic	Code	Code System Progress Report
START	00h	Start POST (BIOS is executing).
CPUTEST	01h	Start CPU register test.
DELAY	02h	Start power-on delay.
DELAYDONE	03h	Power-on delay finished.
KBDBATRDY	04h	Keyboard BAT finished.
DISABSHADOW	05h	Disable shadowing & cache.
CALCCKSUM	06h	Compute ROM CRC, wait for KBC.
CKSUMGOOD	07h	CRC okay, KBC ready.
BATVRFY	08h	Verifying BAT command to KB.
KBDCMD	09h	Start KBC command.
KBDDATA	0ah	Start KBC data.
BLKUNBLK	0bh	Start pin 23,24 blocking & unblocking.
KBDNOP	0ch	Start KBC NOP command.
SHUTTEST	0dh	Test CMOS RAM shutdown register.
CMOSDIAG	0eh	Check CMOS checksum.
CMOSINIT	0fh	Initialize CMOS contents.
CMOSSTATUS	10h	Initialize CMOS status for date/time.
DISABDMAINT	11h	Disable DMA, PICs.
DISABPORTB	12h	Disable Port B, video display.
BOARD	13h	Initialize board, start memory detection.
TESTTIMER	14h	Start timer tests.
TESTTIMER2	15h	Test 8254 T2, for speaker, port B.
TESTTIMER1	16h	Test 8254 T1, for refresh.
TESTTIMER0	17h	Test 8254 T0, for 18.2Hz.
MEMREFRESH	18h	Start memory refresh.
TESTREFRESH	19h	Test memory refresh.
TEST15US	1ah	Test 15usec refresh ON/OFF time.
TEST64KB	1bh	Test base 64KB memory.
TESTDATA	1ch	Test data lines.
TESTADDR	20h	Test address lines.
TESTPARITY	21h	Test parity (toggling).
TESTMEMRDWR	22h	Test Base 64KB memory.
SYSINIT	23h	Prepare system for IVT initialization.
INITVECTORS	24h	Initialize vector table.
8042TURBO	25h	Read 8042 for turbo switch setting.
POSTTURBO	26h	Initialize turbo data.
POSTVECTORS	27h	Modification of IVT.
MONOMODE	28h	Video in monochrome mode verified.
COLORMODE	29h	Video in color mode verified.
TOGGLEPARITY	2ah	Toggle parity before video ROM test.
INITBEFOREVIDEO	2bh	Initialize before video ROM check.
VIDEOROM	2ch	Passing control to video ROM.
POSTVIDEO	2dh	Control returned from video ROM.
CHECKEGAVGA	2eh	Check for EGA/VGA adapter.
TESTVIDEOMEMORY	2fh	No EGA/VGA found, test video memory.
RETRACE	30h	Scan for video retrace signal.
ALTDISPLAY	31h	Primary retrace failed.
ALTRETRACE	32h	Alternate found.
VRFYSWADAPTER	33h	Verify video switches.
SETDISPMODE	34h	Establish display mode.
CHECKSEG40A	35h	Initialize ROM BIOS data area.
SETCURSOR	36h	Set cursor for power-on msg.
PWRONDISPLAY	37h	Display power-on message.
SAVECURSOR	38h	Save cursor position.
BIOSIDENT	39h	Display BIOS identification string.
HITDEL	3ah	Display ìHit <DEL> to ...î message.
VIRTUAL	40h	Prepare protected mode test.
DESCR	41h	Prepare descriptor tables.
ENTERVM	42h	Enter virtual mode for memory test.
ENABINT	43h	Enable interrupts for diagnostics mode.
CHECKWRAP1	44h	Initialize data for memory wrap test.
CHECKWRAP2	45h	Test for wrap, find total memory size.
HIGHPATTERNS	46h	Write extended memory test patterns.
LOWPATTERNS	47h	Write conventional memory test patterns.
FINDLOWMEM	48h	Find low memory size from patterns.
FINDHIMEM	49h	Find high memory size from patterns.
CHECKSEG40B	4ah	Verify ROM BIOS data area again.
CHECKDEL	4bh	Check for <DEL> pressed.
CLREXTMEM	4ch	Clear extended memory for soft reset.
SAVEMEMSIZE	4dh	Save memory size.

COLD64TEST	4eh	Cold boot: Display 1st 64KB memtest.
COLDLOWTEST	4fh	Cold boot: Test all of low memory.
ADJUSTLOW	50h	Adjust memory size for EBDA usage.
COLDHITEST	51h	Cold boot: Test high memory.
REALMODETEST	52h	Prepare for shutdown to real mode.
ENTERREAL	53h	Return to real mode.
SHUTDOWN	54h	Shutdown successful.
DISABA20	55h	Disable A20 line.
CHECKSEG40C	56h	Check ROM BIOS data area again.
CHECKSEG40D	57h	Check ROM BIOS data area again.
CLRHITDEL	58h	Clear ìHit <DEL>ì message.
TESTDMAPAGE	59h	Test DMA page register file.
VRFYDISPMEM	60h	Verify from display memory.
TESTDMA0BASE	61h	Test DMA0 base register.
TESTDMA1BASE	62h	Test DMA1 base register.
CHECKSEG40E	63h	Checking ROM BIOS data area again.
CHECKSEG40F	64h	Checking ROM BIOS data area again.
PROGDMA	65h	Program DMA controllers.
INITINTCTRL	66h	Initialize PICs.
STARTKBDTEST	67h	Start keyboard test.
KBDRESET	80h	Issue KB reset command.
CHECKSTUCKKEYS	81h	Check for stuck keys.
INITCIRCBUFFER	82h	Initialize circular buffer.
CHECKLOCKEDKEYS	83h	Check for locked keys.
MEMSIZEMISMATCH	84h	Check for memory size mismatch.
PASSWORD	85h	Check for password or bypass setup.
BEFORESETUP	86h	Password accepted.
CALLSETUP	87h	Entering setup system.
POSTSETUP	88h	Setup system exited.
DISPPWRON	89h	Display power-on screen message.
DISPWAIT	8ah	Display ìWait...î message.
ENABSHADOW	8bh	Shadow system & video BIOS.
STDCMOSSETUP	8ch	Load standard setup values from CMOS.
MOUSE	8dh	Test and initialize mouse.
FLOPPY	8eh	Test floppy disks.
CONFIGFLOPPY	8fh	Configure floppy drives.
IDE	90h	Test hard disks.
CONFIGIDE	91h	Configure IDE drives.
CHECKSEG40G	92h	Checking ROM BIOS data area.
CHECKSEG40H	93h	Checking ROM BIOS data area.
SETMEMSIZE	94h	Set base & extended memory sizes.
SIZEADJUST	95h	Adjust low memory size for EBDA.
INITC8000	96h	Initialize before calling C800h ROM.
CALLC8000	97h	Call ROM BIOS extension at C800h.
POSTC8000	98h	ROM C800h extension returned.
TIMERPRNBASE	99h	Configure timer/printer data.
SERIALBASE	9ah	Configure serial port base addresses.
INITBEFORENPX	9bh	Prepare to initialize coprocessor.
INITNPX	9ch	Initialize numeric coprocessor.
POSTNPX	9dh	Numeric coprocessor initialized.
CHECKLOCKS	9eh	Check KB settings.
ISSUEKBDID	9fh	Issue keyboard ID command.
RESETID	a0h	KB ID flag reset.
TESTCACHE	a1h	Test cache memory.
DISPSOFTERR	a2h	Display soft errors.
TYPEMATIC	a3h	Set keyboard typematic rate.
MEMWAIT	a4h	Program memory wait states.
CLRSCR	a5h	Clear screen.
ENABPTYNMI	a6h	Enable parity and NMIs.
INITE000	a7h	Initialize before calling ROM at E000h.
CALLE000	a8h	Call ROM BIOS extension at E000h.
POSTE000	a9h	ROM extension returned.
DISPCONFIG	b0h	Display system configuration box.
INT19BOOT	00h	Call INT 19h bootstrap loader.
LOWMEMEXH	b1h	Test low memory exhaustively.
EXTMEMEXH	b2h	Test extended memory exhaustively.
PCIENUM	b3h	Enumerate PCI busses.

Go back to MPCU Boot Procedure

Go back to LWL_INT Block Diagram

Go back to MPCU description

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Section

5

RF System

Introduction

As in the previous Harmony/Symphony/Sonata product line, the already successful local coil concept, Integrated Panoramic Array, has been taken to the level: Tim - Total imaging matrix. Tim stands for the ultimate in receive coil coverage of the patient, with the new and revolutionary Matrix coils. Matrix coils are specially designed coils which have several coil elements - anywhere from 4 to 24 elements depending on the coil - placed in groups, or clusters, in such a way that the individual coil element can be read out and combined to produce three different modes. Depending on the selected mode, parallel acquisition technique (PAT) imaging and classical CP imaging techniques can be made. Due to the arrangement of the coil element groups PAT imaging is possible in all directions allowing PAT factors (speed factors) from 2 to 4 in any one direction, depending on which matrix coils are involved.

The emphasis in the Tim concept is simple: maximum coverage, maximum signal quality and maximum speed. This translates into an improved workflow, greater patient comfort and higher revenues.

Improved workflow because the matrix coil concept allows the user the flexibility to select any type of examination without having to change coils and reposition the patient. The user no longer sees examinations using explicit individual local coils, but for any given examination type the required number of matrix coils, there are six in total covering the complete body, are placed on the patient to cover the desired region of interest. Greater **patient comfort** because the matrix coils allow PAT factors up to 4 meaning shorter examination times. Also, patient need not be repositioned for additional exams if these be necessary further reducing overall examination times. **Higher revenues** realized though a higher patient throughput.

Complimenting this new matrix coil technology is a new intelligent coil control system coupled with a new patient table drive system. The user only requires to position the slices within the region of interest and the patient table will automatically center the ROI into the magnet's ISO center. The coil control electronics are capable of detecting the position and orientation of the coils and automatically select the correct coils without any user intervention, providing a true plug-and-play capability.

Figure 42 *RF System Block Diagram*

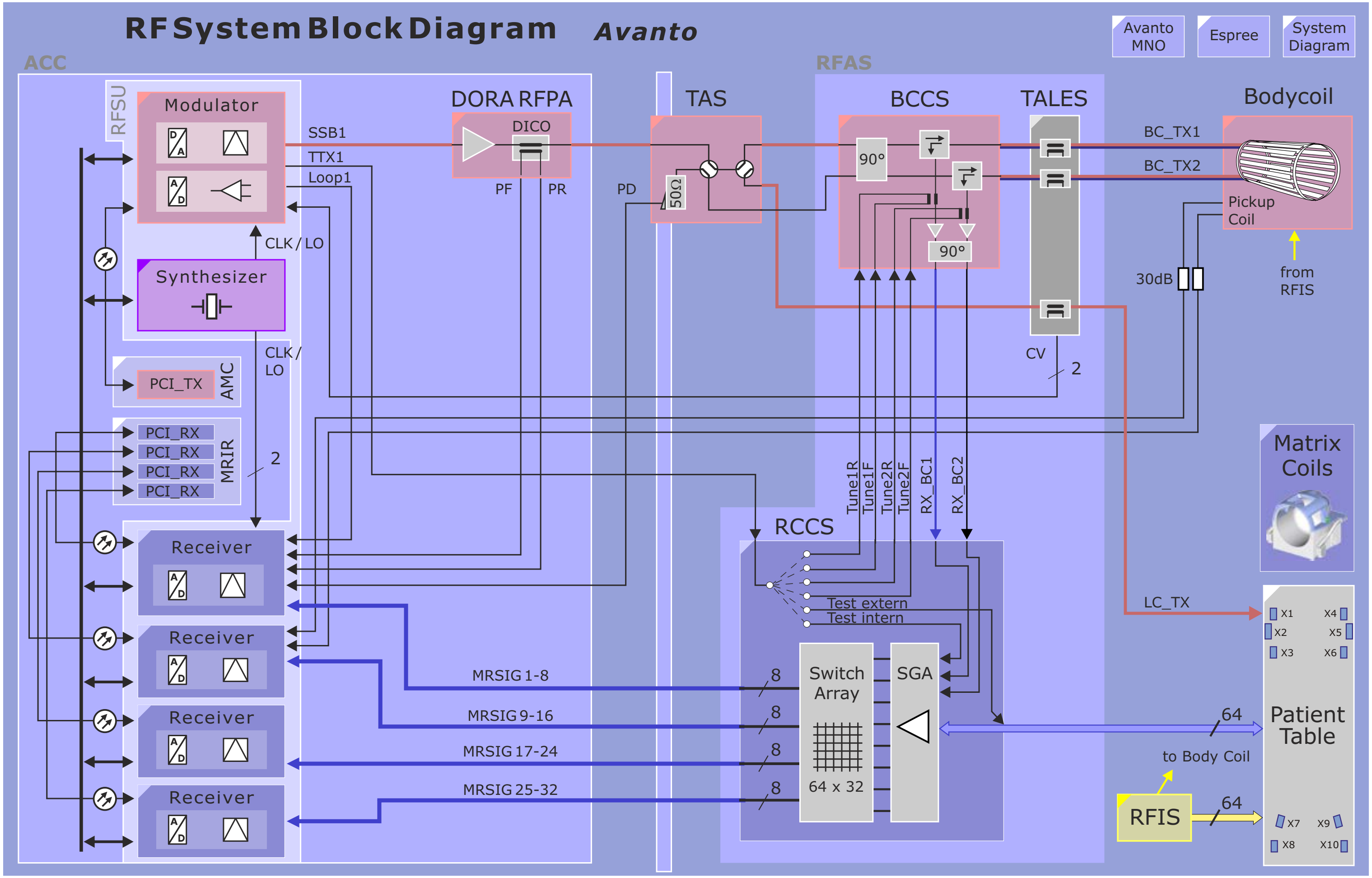


Figure 43 *RF System Block Diagram*

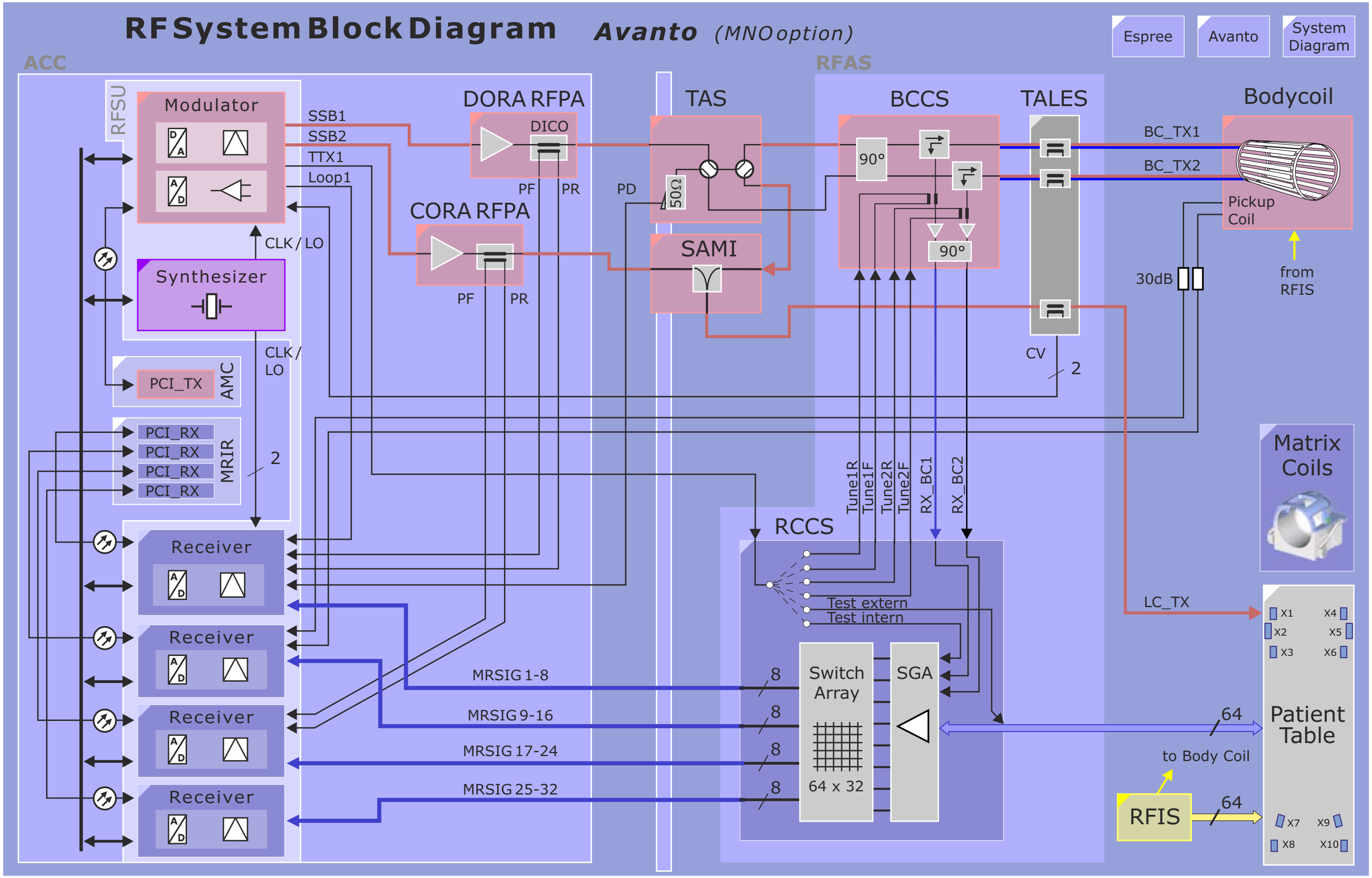
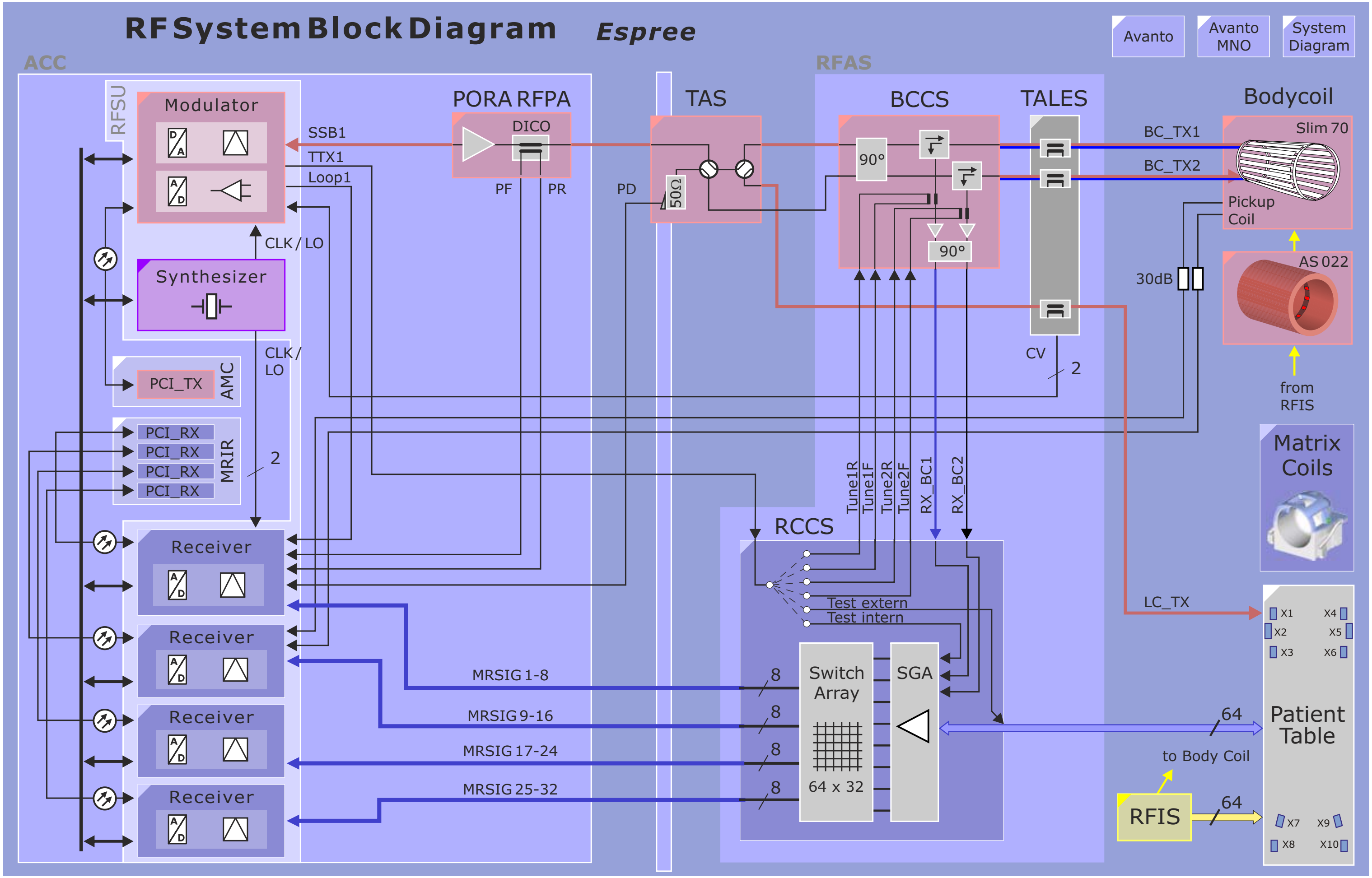


Figure 44 *RF System Block Diagram*



RF Signal Unit (RFSU)

Overview

The RFSU is a modular system consisting of three components:

- Modulator board
- Receiver board
- Synthesizer board
- Transmitter board

All components are fully digital and realized in the form of PC boards placed in a rack and connected to a common backplane over 96 pole connectors. All RF signal inputs and outputs are available as coax connectors at the front plate of each board.

The role of the RFSU can be best summarized as being low-to-high and high-to-low frequency converters. The RF pulse modulation and MR signal demodulation are performed by DSPs on the PCI_TX and PCI_RX boards respectively. The Modulator digital-to-analog converts the digitally modulated RF pulses from the PCI_TX and then mixes the result up to the required system frequency. Conversely, the Receiver mixes the MR signal down to an IF signal and A/D converts this for the PCI_RX which then does the filtering and demodulation digitally.

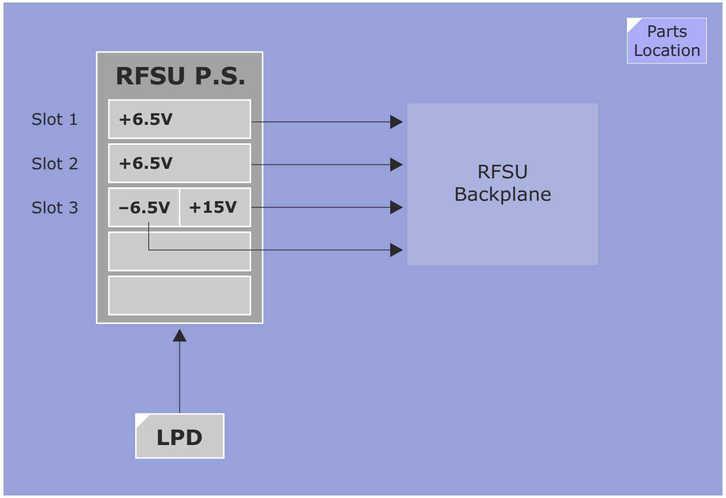
There are no adjustments required and there are no filters to clean and maintain.

Due to its modular design the RFSU can be expanded to include a second RF Modulator and up to 3 additional Receiver Modules for a total of 32 dedicated receive channels.

Power Supply

The RFSU has its own power supply. The power supply outputs are connected to the RFSU backplane and distributed to the RFSU boards over the backplane.

Figure 45 *RFSU Power Supply*



Modulator

Different types of Modulator boards exist. Early systems had a modulator capable of imaging hydrogen frequency only (63.6 MHz). Newer systems have Modulators with an extended frequency range for use on 1.5, 3 and 7 T systems, as well as the multi-nuclear spectroscopy option. You will find a complete list of available Modulator boards in the Spare Parts Catalogue.

Inputs

The digitally modulated single side-band pulse **SSB_DIG1_TX** generated on the PCI_TX board in the AMC is delivered to the Modulator via a bi-directional, high-speed (640MBit/s each direction), optical fiber connection located at the rear of the board.

The 10 MHz clock **CLK 10** is required for synchronizing the data transfer and for digitalization of the digital IF.

The local oscillator signal **LO_TRA** is used to mix the IF signal from the D/A converter up to the system frequency.

The **CV** and **OFFSET** signals are multiplexed signals coming from the TALES representing the measured forward and reflected RF transmit voltages applied to the body coil. It is A/D converted at a 500 kHz sampling rate and sent to the AMC over the SSB_DIG1_TX fiber optic line. These signals are used by the RF Safety Watchdog (RFSWD) software for calculation of the SAR.

Function

A de-serializer converts the serial data stream into parallel data blocks which are then sent to the DAC for conversion.

The DAC output is the SSB signal in IF (intermediate frequency) signal of around 2 MHz. This is mixed up to the system frequency of (nominally 63.6 MHz ±250 kHz) with local oscillator signal coming from the Synthesizer board D10. The signal is filtered for a frequency spectrum free of spurious and inter-modulation harmonics.

The amplitude of the resultant RF signal is put through a two-stage attenuator matrix consisting of a **6 dB** and a **12 dB** attenuator. The attenuators are used to reduce the power levels when using transmit-capable local coils in order to sustain maximum dynamic range of the DAC.

Outputs

The final **SSB** signal is applied over a switch array to one of seven outputs. The data for switch selection and attenuator selection as well as the frequency selection for the Synthesizer is also sent to the Modulator over the high-speed fiber optic line.

The maximum output amplitude is 3dBm for SSB and TTX signals and 16dBm for the Loop signals.

LEDs

The LEDs display the attenuator (ATT) selection, the output selection (OUTSEL), active RF transmission (RFON) and the FPGA status (FPGA_OK and LINKERR).

NOTE **NOTE**: The LEDs are not active until the sequence is running!

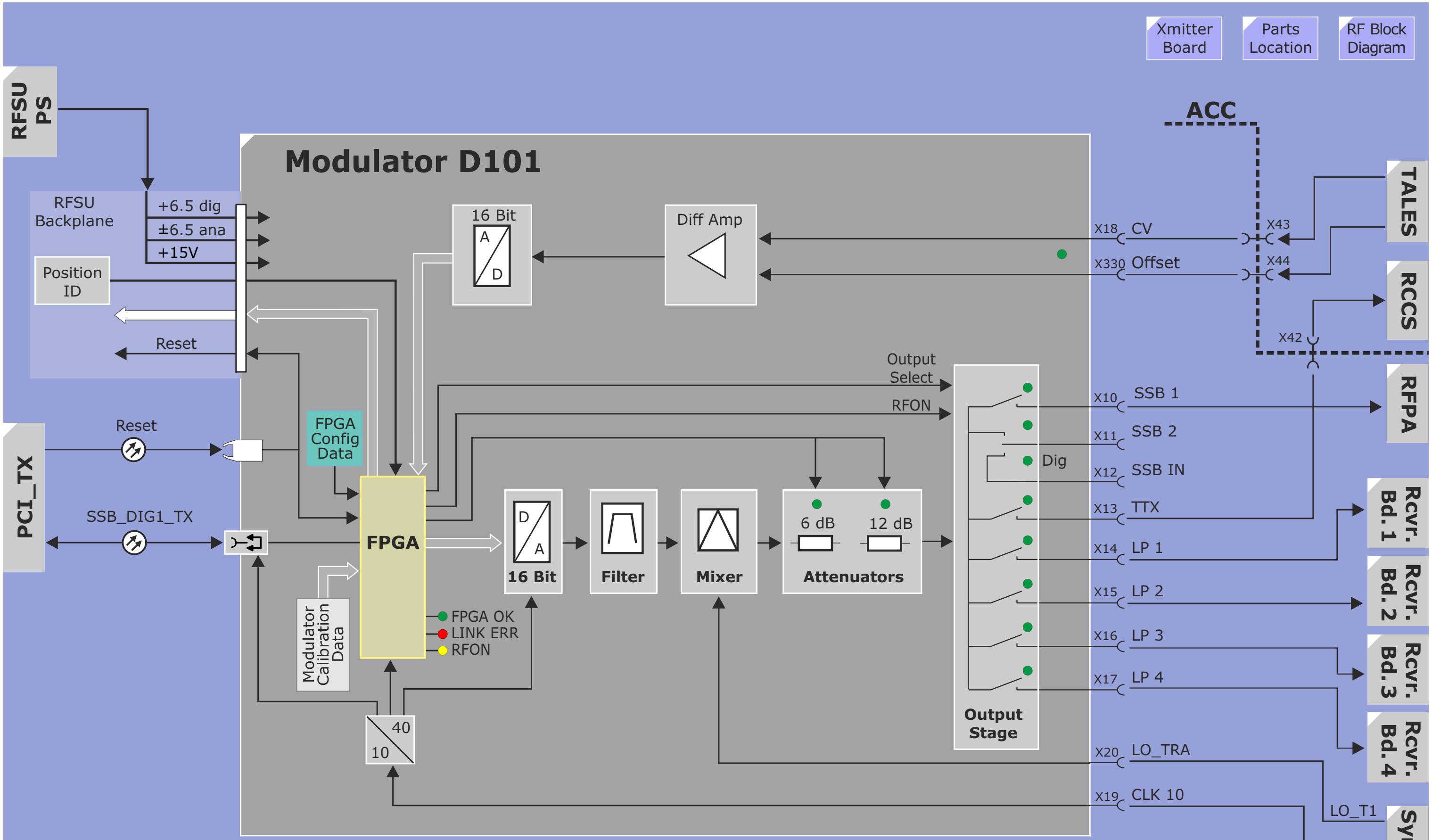
Switches (only Modulator part no 100 18 301)

A dip switch setting must be adapted to the system frequency! Check the label on the board.

Specifications

Value	Specification
Center Frequency Range	63.6 MHz ±150 kHz
Bandwidth	250 kHz

Figure 46 *Modulator Block Diagram*



NOTE: There are different versions of this board. See Spare Parts Catalog for details.
NOTE: The MNO option requires the 7T Modulator

Synthesizer

Inputs

Control inputs for determining the frequency and phase of the NCOs.

Function

The synthesizer uses a temperature-stabilized reference oscillator to generate a highly-stable 10 MHz clock from which all system clocks are derived. The local oscillator signals are generated by two Numerically Controlled Oscillators (NCO) both fed with a 160 MHz clock created from the 10MHz reference oscillator. The LO and clock signals are required by the Receiver to perform frequency mixing from the system frequency down to an IF frequency of around 2MHz

The top NCO is used for hydrogen and all MKO nucleus frequencies (see Figure 47 below). The second one only is only needed for generation of the decoupling TX nucleus frequency used for special spectroscopy "decoupling experiments".

NOTE For the MKO (multi nucleus spectroscopy) option a new Modulator and Synthesizer are necessary. Their functions are described here as well.

Outputs

The output signals of either NCO can be coupled to the six LO output connectors via four fast-acting switches. The switches control signals are also originating from the Modulator.

All outputs are active as soon as power is applied.

Signal	Description	Level
LO T1	LO for Modulator 1	-1 ±0,1 dBm on 50Ω
LO T2	LO for Modulator 2 (MKO option)	-1 ±0,1 dBm on 50Ω
LO R1 - 4	LO for Receivers 1 - 4	-1 ±0,1 dBm on 50Ω
10_M1	10 MHz clock for Modulator 1	3 ±0.5 dBm on 50Ω
10_M2	10 MHz clock for Modulator 2	3 ±0.5 dBm on 50Ω
10_R1-4	10 MHz clock for Receiver 1-4	3 ±0.5 dBm on 50Ω

LEDs

Both 6.5V and 12V LEDs must light indicating voltages are ok.

Specifications

Value	Specification
Frequency Range	10 to 120 MHz
Frequency Bandwidth	300 kHz
Frequency Instability	4*10E-10 pp max over 5min
Amplitude Instability	0,02dB max

Figure 47 *Spectroscopy Frequencies*

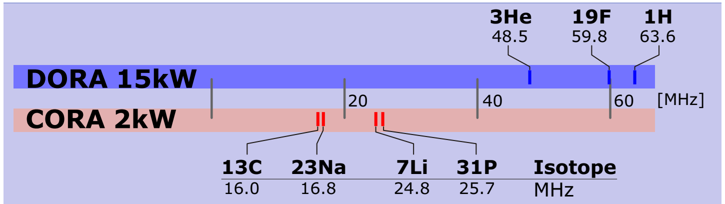
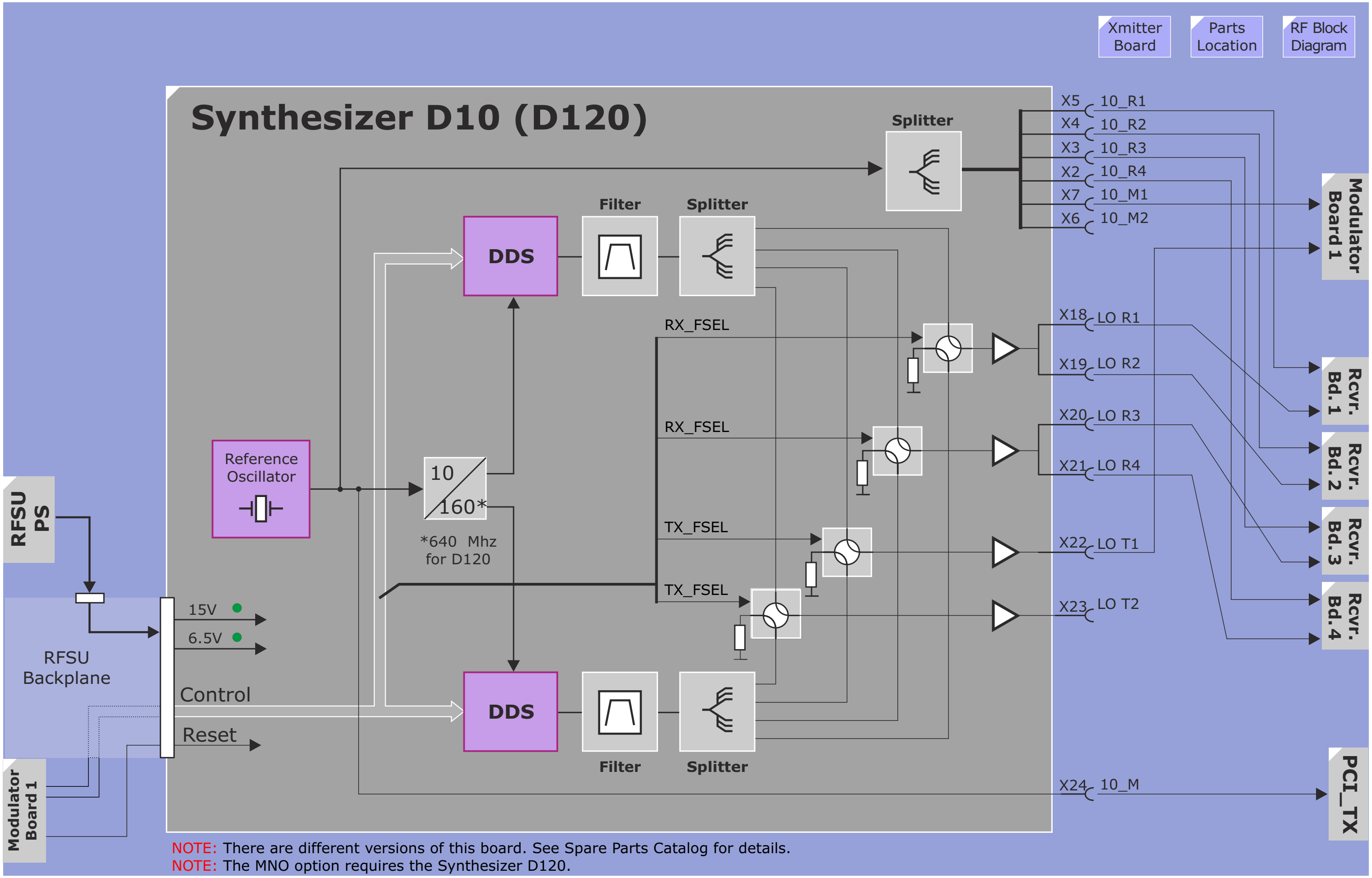


Figure 48 *Synthesizer Block Diagram*



Transmitter Board

This board is a redesign of the Modulator and Synthesizer boards which have now been combined to one board. Several improvements have been incorporated for better signal quality and reliability has been improved. The function remains the same as for the older boards.

Only the differences will be mentioned here.

NOTE The Transmitter board must be plugged into the "Modulator" slot.

Inputs

The same

Function

The NCOs are now integrated into an FPGA. The digitalization clock has been increased from 160 to 320 MHz.

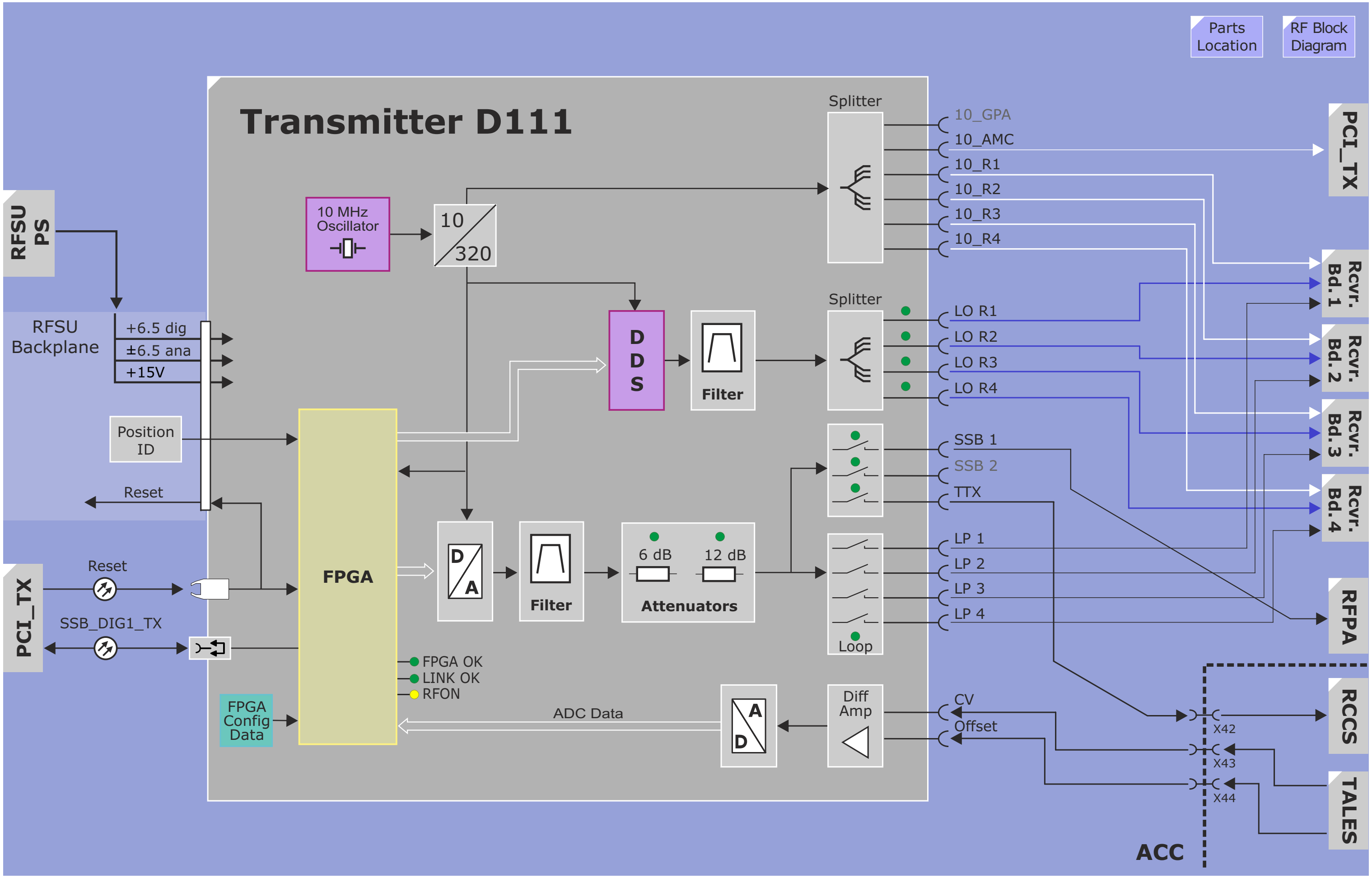
Outputs

The outputs and their levels are the same.

LED

PLL LOCK - indicates an internal synchronization process is ok.

Figure 49 *Transmitter Block Diagram*



Receiver

The Receiver creates a digital IF signal from the MR echo signals coming from the RCCS which will be digitally demodulated and filtered by the PCI_RX in the MRIR.

Inputs

Signal	Description	Level
MRSIG 1-8	MR echo from receive coils	3 dBm max
PF (Mod 1)	RFPA forward power	3 dBm max
PR (Mod 1)	RFPA reflected power	3 dBm max
PD	Sampled power level at the 50 ohm dummy load in the TAS	3 dBm max
Loop	loop testing of RFSU components	16 dBm max
CLK 10	10 MHz clock used for internal synchronization	3 ± 0.5 dBm on 50Ω
LO REC (LO R1-4)	Local oscillator for mixer	-1 ±0.1 dBm on 50Ω

Function

The Receiver board functions as a signal converter. First, the received MR signals picked up by the receive coils are at the nominal system frequency of 63.6 MHz. The Mixer stages reduces this frequency to an IF of approximately 1 MHz. They are then compressed and digitized by a 14-bit ADC at a 10 MHz sample rate and finally sent to the MRIR over a bi-directional, high-speed optical fiber link. Compression of the signal before acquisition allows the use of a lower resolution ADC (14 bit vs 16 bit) which helps to reduce the overall data volume. Remember, there are 32 receive channels and every bit reduction helps overall data throughput. Although a 14-bit DAC is used the dynamic range does not suffer, it is the same as a 16 bit system. Additionally, the increased sampling rate (10 MHz) together with a digital decimation filter the effective ADC resolution is increased to between 21-24 bits of resolution, depending on the pixel bandwidth. The drawback of having to de-compress is eliminated since it is not performed by software but in hardware on-the-fly.

Outputs

The digitized signals are sent via a high-speed fiber optic line to the PCI_RX board for demodulation and filtering.

LEDs

LED	Description
PF/PR/PD	Signifies these three inputs are being input.
MRSIG	Signifies the MR signal inputs are being input
FPGA 1,2 OK	Lights green when FPGA successfully loaded
LINK 1,2 Error	Lights red when an error in the fiber optic output section occurs
Loop	Signifies the LOOP inputs are activated. Active during service testing.
RX ON	Indicates the system is in receive mode

Specifications

The code of the board positions is read in over the optical interface.

Value	Specification
Center Frequency	63.6 MHz
Frequency Range	150 kHz
0.1dB Bandwidth	250 kHz
Max Input Level	± 1.2 dBm
Stability (5 min.)	≤ 0.01 dB
Receiver resolution	18 bit effective @10MHz sample rate
Noise Figure	12 dB

NOTE See Spare Parts catalog. There are different versions of this board!

Figure 50 *Receiver Block Diagram*

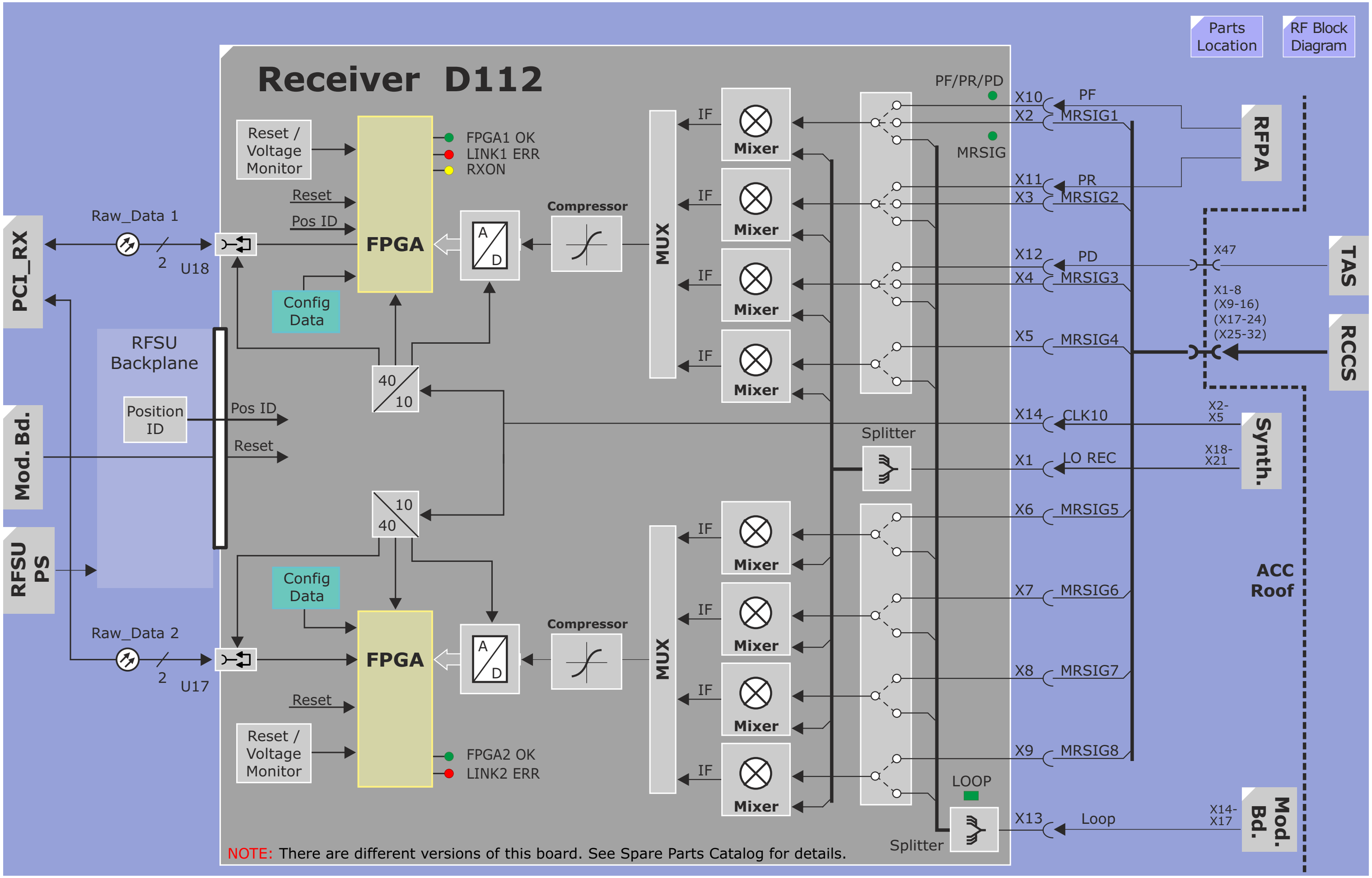
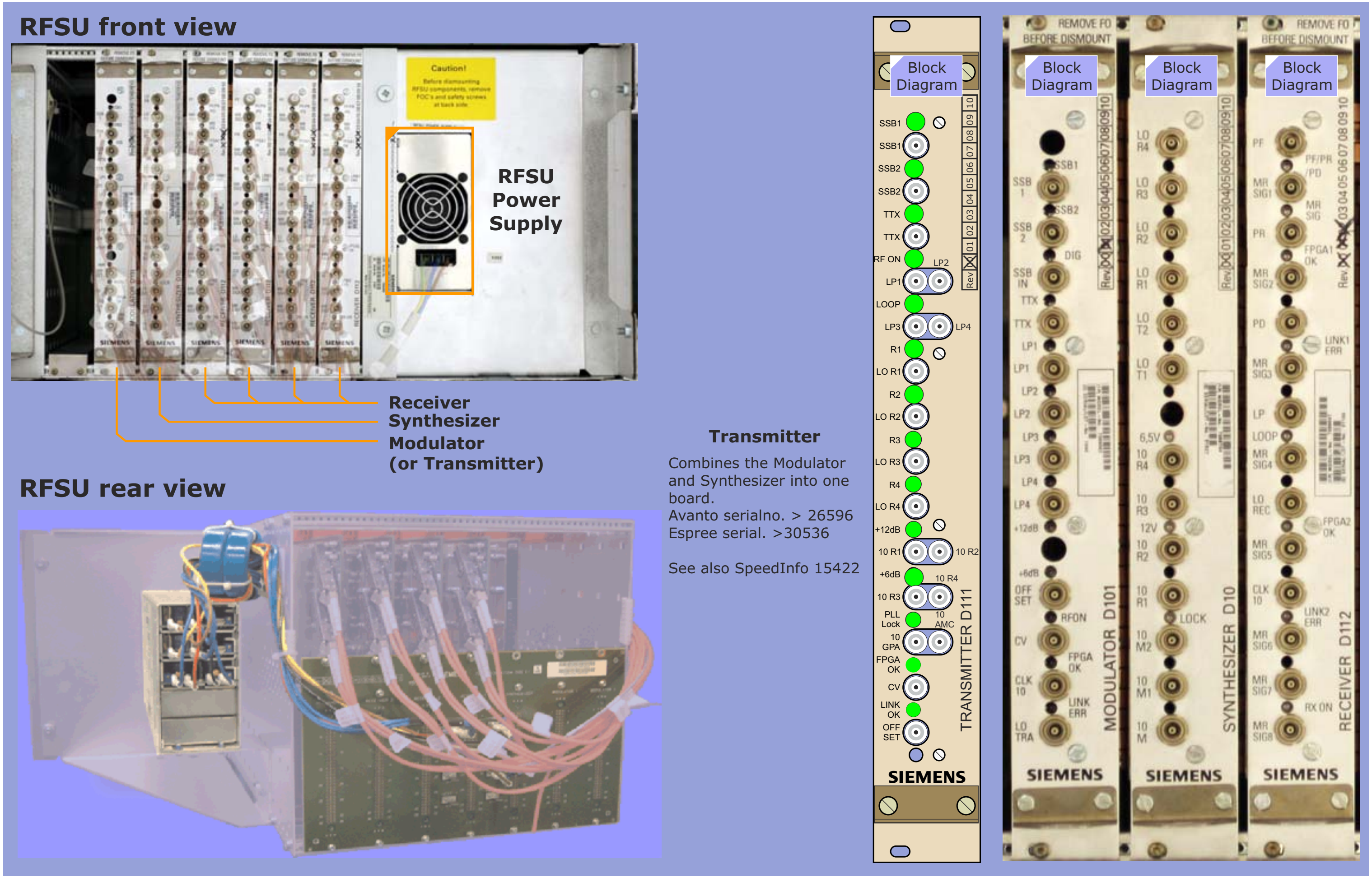


Figure 51 *RFSU Layout*



RF Power Amplifier (DORA)

Function

Power Up

To power the amplifier a CAN command is sent to set the internal **enable** signal. The **RFPA_ON** signal from the LWL_INT must also be present. With both signals present, the **Start Up** LED will light and stay on until the power supply voltages have reached their proper levels after which the **Start Up** LED goes OUT and the **Ready** LED lights and to signify the amplifier is operational.

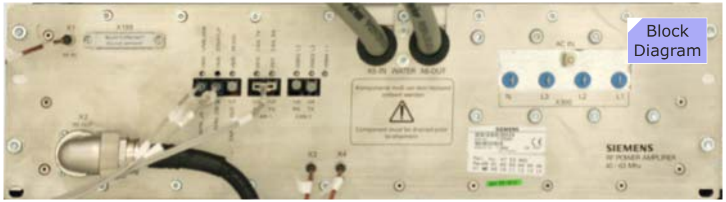
Monitoring

The RFPA has several internal monitoring circuits monitoring several vital functions:

- over voltage or over current of the power supply
- excessive forward (5%) or reflected (approx 30%) output power levels (**RF Power**)
- unblank duty-cycle (6-8%)
- power stage temperature (50°C)

In the event of an internal failure or an operational limit of the amplifier has been exceeded the amplifier provides a status report via the CAN bus and the **READY** LED goes out.

Figure 52 *DORA RFPA Front Panel*



Inputs

Signal	Description
AC_IN	Three-phase AC voltage input (93V phase to neutral). An internal power supply generates all required voltages.
RF_IN	Input of RF signal to be amplified. The nominal input level for the full output power level of 15kW is 0dBm.
RFPA_UNB	To reduce noise and loss of the MR echo during reception the amplifier is blanked during the receive cycle. This is accomplished with the fiber optic signal RFPA_UNB. When signal is active (light on), the amplifier is activated.
RFPA_ON	The purpose of this signal is to disable the amplifier, a requirement for the SAR monitoring. The RFPA will be enabled when the signal is active (light on).
Enable_Out	A copy of the RFPA_On signal as output to an additional RF amplifier.
CAN1, 2	Fiber optic CAN bus communication interface.

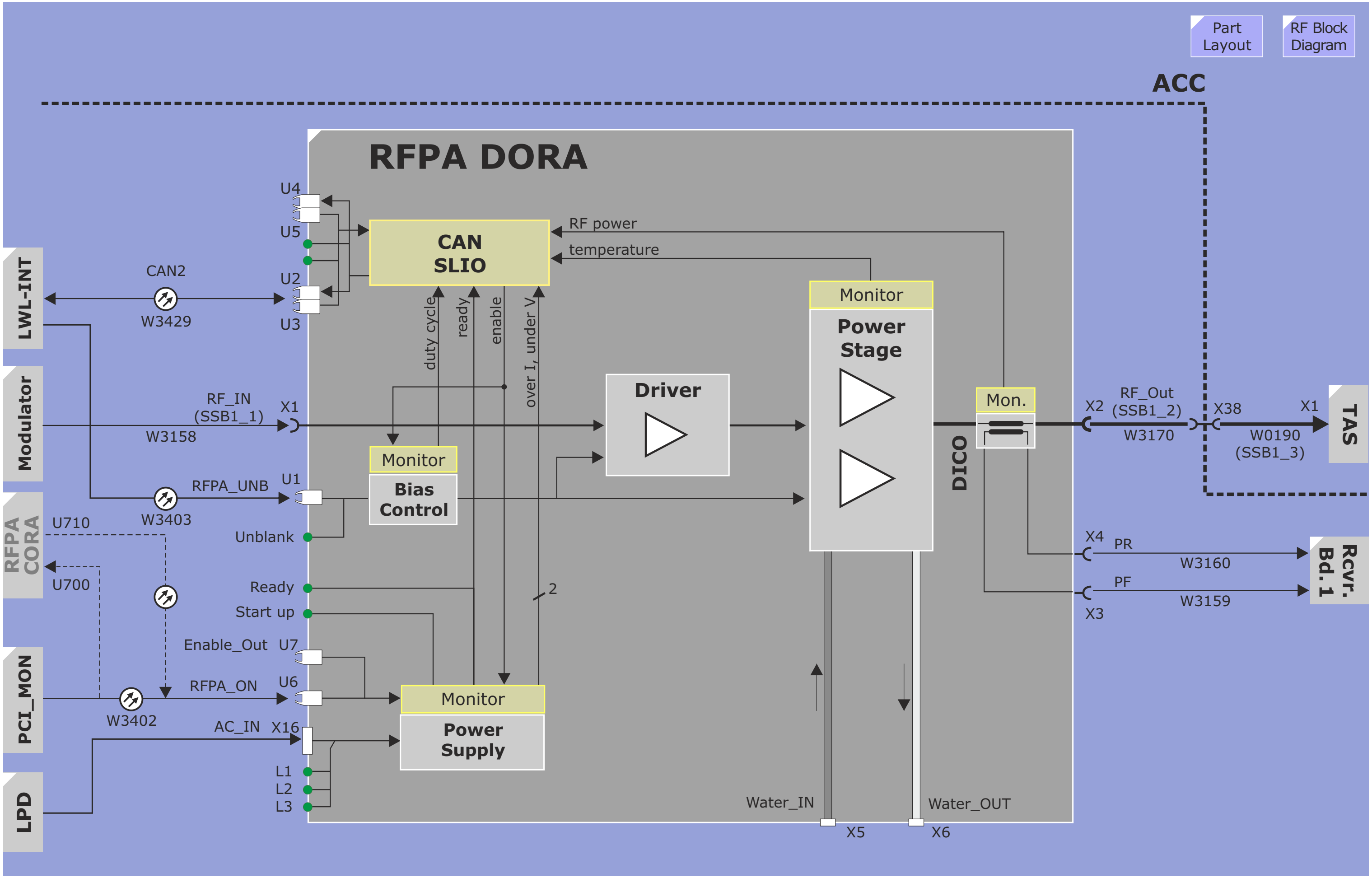
Outputs

Signal	Description
PF, PR	Directional coupler (DICO) outputs of the forward and reflected power levels of the RFPA output.
RF_OUT	This is hopefully where the amplified RF comes out.

LEDs

LED	Description
UNBLK	Lights when a gating pulse is applied.
Start Up	RFPA put into power-up mode (command via CAN).
READY	Amplifier power up completed and ready.
CAN TX	Lights when activity on CAN bus.
CAN RX	Lights when activity on CAN bus.
L1-L3	AC Power supplied to unit.

Figure 53 *DORA RF Power Amplifier Block Diagram*



RF Power Amplifier (PORA)

The functional description is the same as for DORA.

The maximum output power is **22.5 kW**.

Figure 54 *PORA Front Panel*

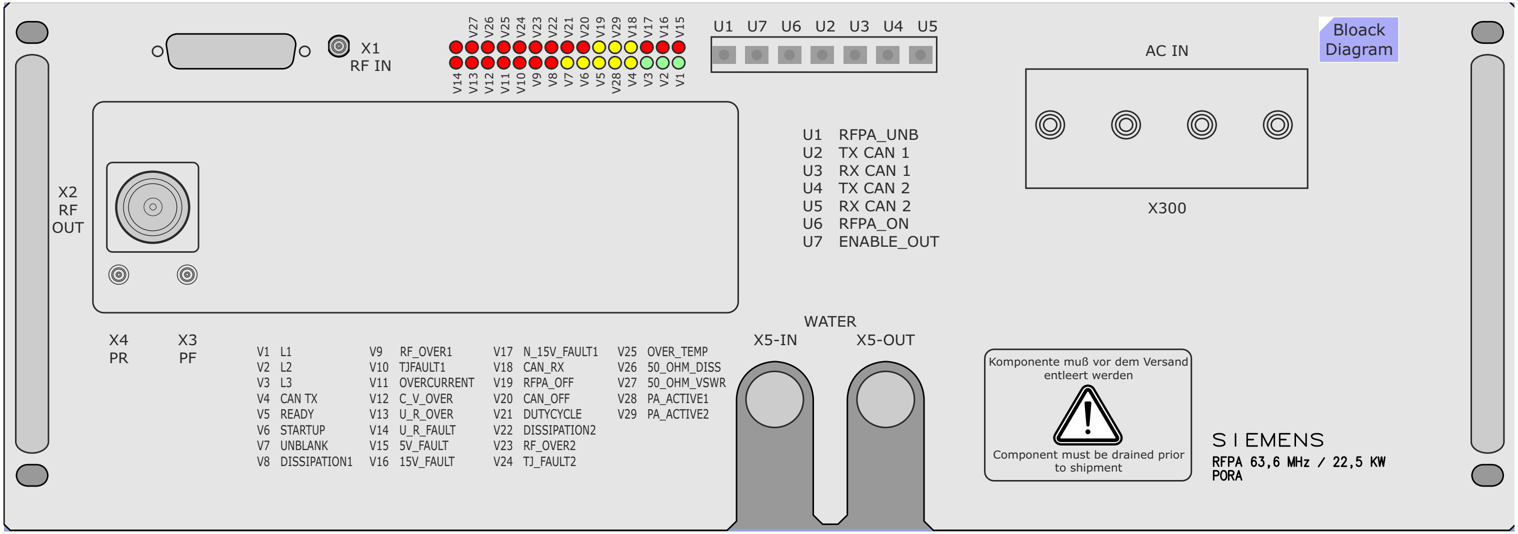
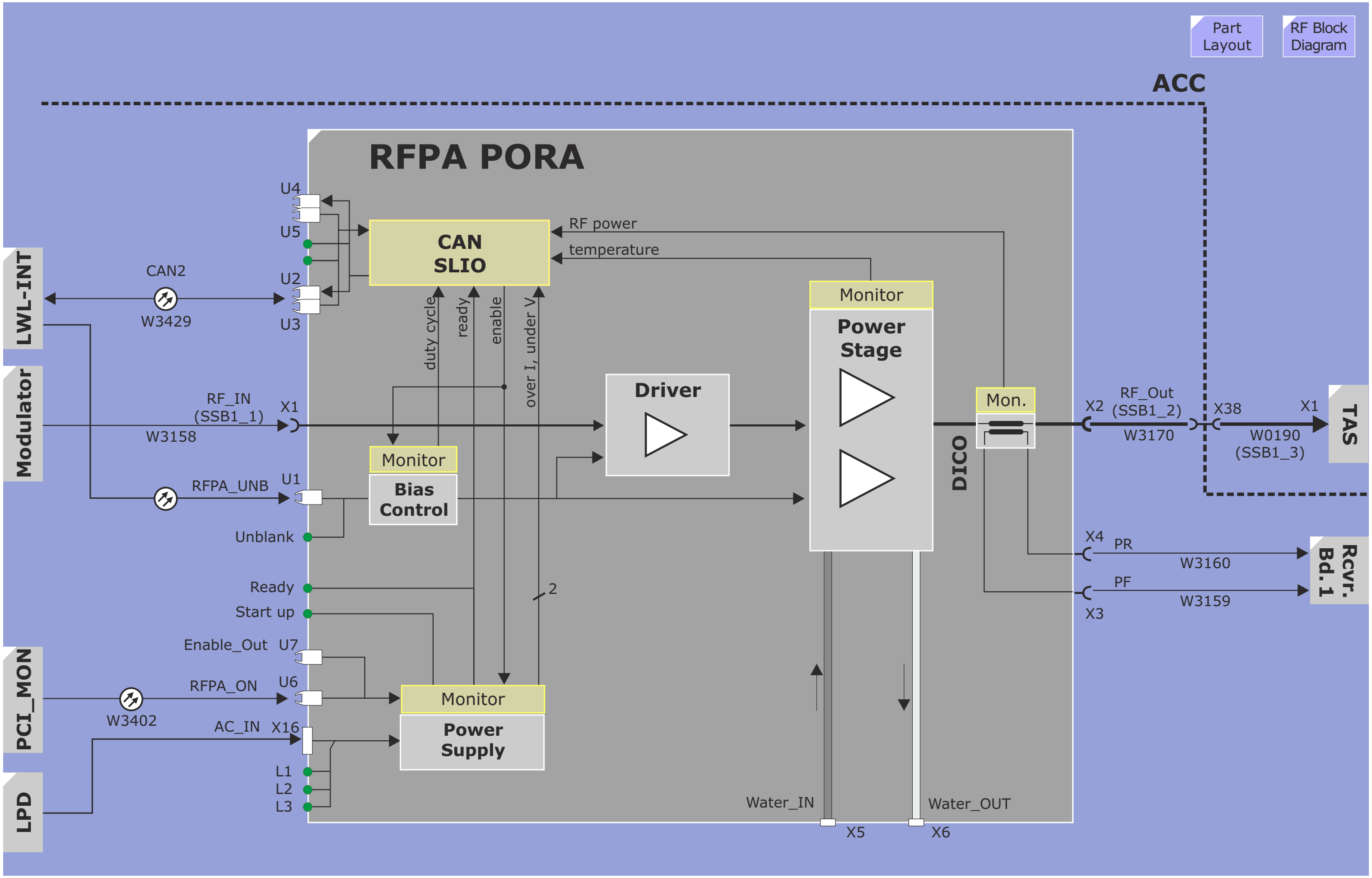


Figure 55 *PORA RF Power Amplifier Block Diagram*



RF Power Amplifier (CORA)

Function

Power Up

To bring the amplifier up to operation the **PA_ON** signal must be applied. When the amplifier is ready, it will set the **Ready** signal (light on). This signal is routed to the RFPA_On input of the DORA amplifier. This will tell the AMC via CAN Bus CORA is okay and will cause the AMC to enable DORA amplifier via CAN bus; the Start up - LED in DORA lights up. Finally the Start up - LED switches off and the Ready LED in the DORA lights up. Both RFPAs are ready now.

Monitoring

The CORA has integrated monitoring circuitry for various internal functions. If any of these monitored functions fails, the **Ready** condition is extinguished (LED goes out) and fiber optic signal to DORA RFPA is removed (light out).

Two LEDs represent temperature related errors **TS-ERR** and **HOT-Sink**.

In case of an error the Ready fiber optic signal to the RFPA_ON input of the DORA RFPA will be set low (light out) causing the DORA RFPA to shut down. THis will be reported by the DORA's CAN unit back to the MR system control unit (AMC). Currently, the AMC will react by setting the PA_ON signal to CORA low and hence disable CORA and DORA.

Inputs

Signal	Description
AC_IN	The two-phase AC primary voltage of 230V. An internal power supply generates all required voltages.
RF_IN	The nominal input level for the full output power level is 0dBm.
RFPA_UNB	To reduce noise and loss of the MR echo during reception the amplifier is blanked during the receive cycle. This is accomplished with the fiber optic signal RFPA_UNB. When signal is active (light on), the amplifier is activated.
PA_ON	An enable signal (light on) required to bring the amplifier to operating condition. The purpose of this signal is to be able to disable the amplifier, a requirement for the SAR monitoring.

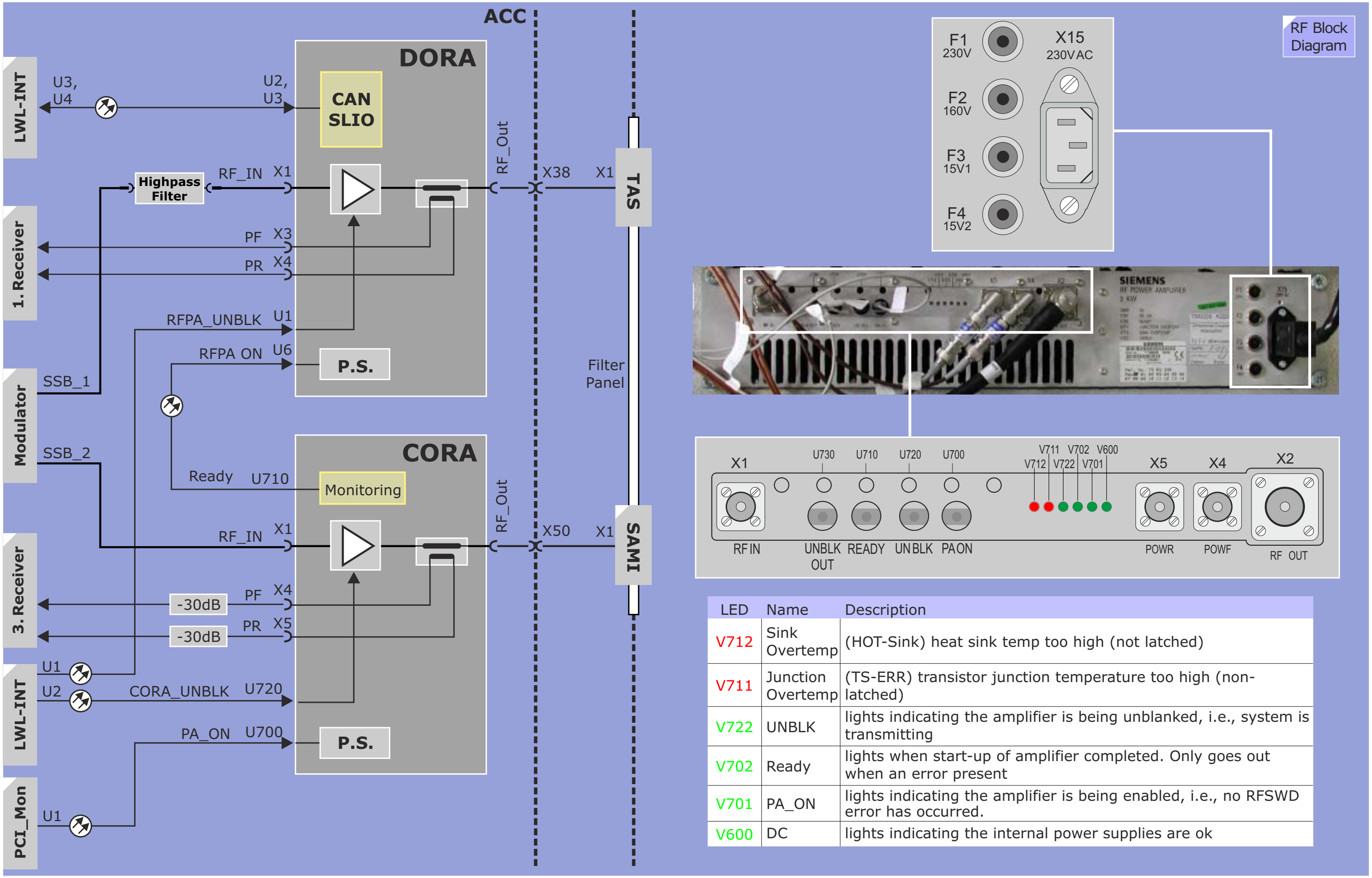
Outputs

Signal	Description
PF, PR	Directional coupler (DICO) outputs of the forward and reflected power levels of the RFPA output
RF_OUT	This is hopefully where the amplified RF comes out

LEDs

LED	Description
DC	AC Power supplied to unit
PA_ON	Remote power on signal present
READY	Amplifier start-up completed, system ready
UNBLK	Lights when a gating pulse is applied to the amplifier
TS-ERR	Transistor junction temperature too high (**non-latched**)
HOT-TSINK	Heat sink temperature too high (**non-latched**)

Figure 56 *RFPA CORA*



LED	Name	Description
V712	Sink Overtemp	(HOT-Sink) heat sink temp too high (not latched)
V711	Junction Overtemp	(TS-ERR) transistor junction temperature too high (non-latched)
V722	UNBLK	lights indicating the amplifier is being unblanked, i.e., system is transmitting
V702	Ready	lights when start-up of amplifier completed. Only goes out when an error present
V701	PA_ON	lights indicating the amplifier is being enabled, i.e., no RFSWD error has occurred.
V600	DC	lights indicating the internal power supplies are ok

RF Application System (RFAS)

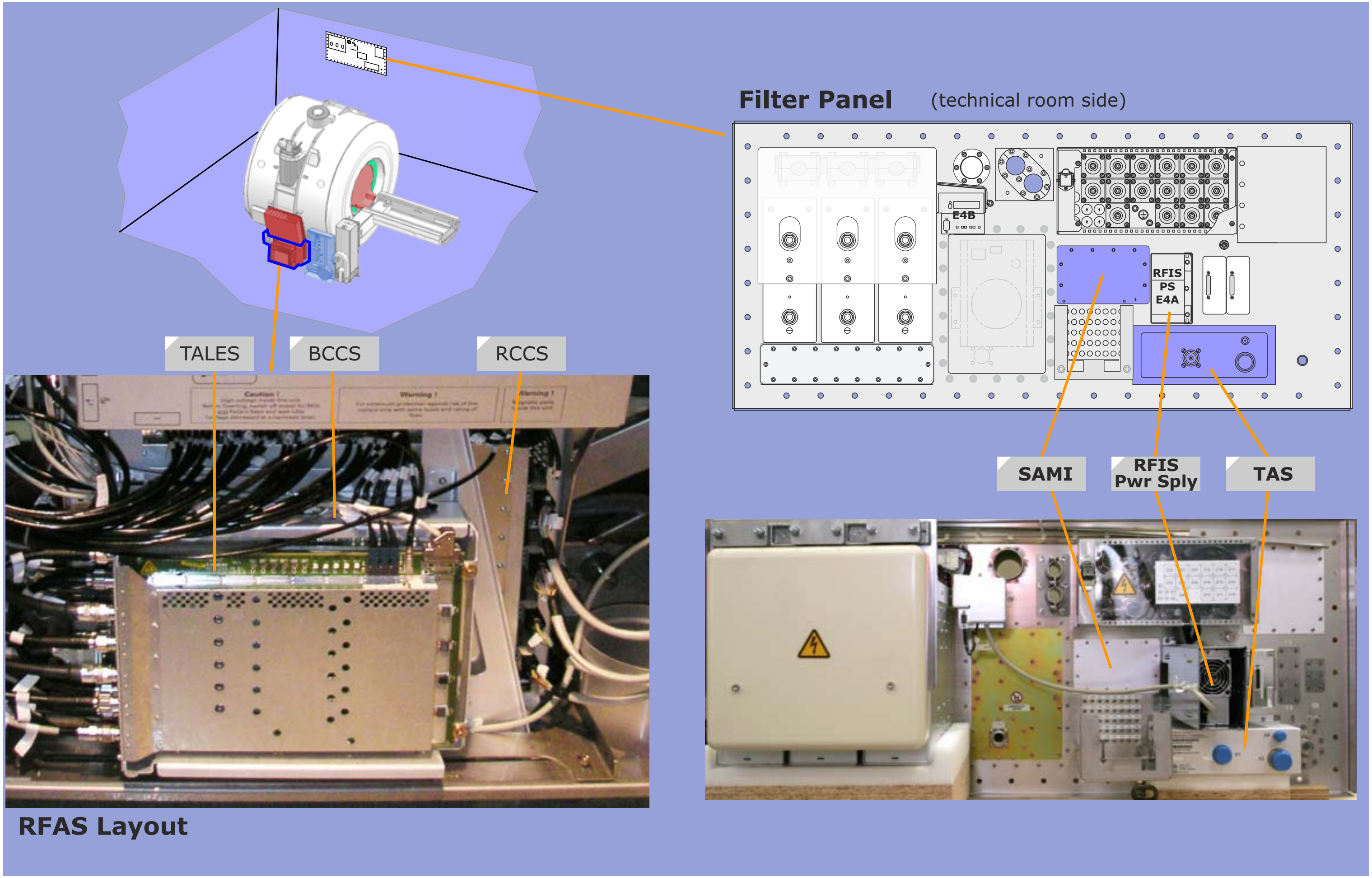
The RFAS is that group of components which are needed to apply the RF transmit and receive signals between the various transmit and receive coils and the RF front-end (Modulator and Receiver).

The RFAS consists of the components

- TAS_3T, SAMI_3T
- BCCS
- RCCS
- TALES

The accompanying diagram is one page down.

Figure 57 *RFAS Parts Layout*



TAS_3TM

Mechanical Switching

The Transmit Antenna Selector (TAS) version 3TM (**3T** = for use on systems with a max RF transmit power of 35 kW; **M** = measure output of the dummy load voltage) supplies mechanical switching of the RF transmit signal to two output paths.

50Ω Termination

In addition it contains a 35kW (PEP) 50Ω dummy load used for termination of the 90° hybrid of the BCCS and the RFPA for running service test and calibration loops.

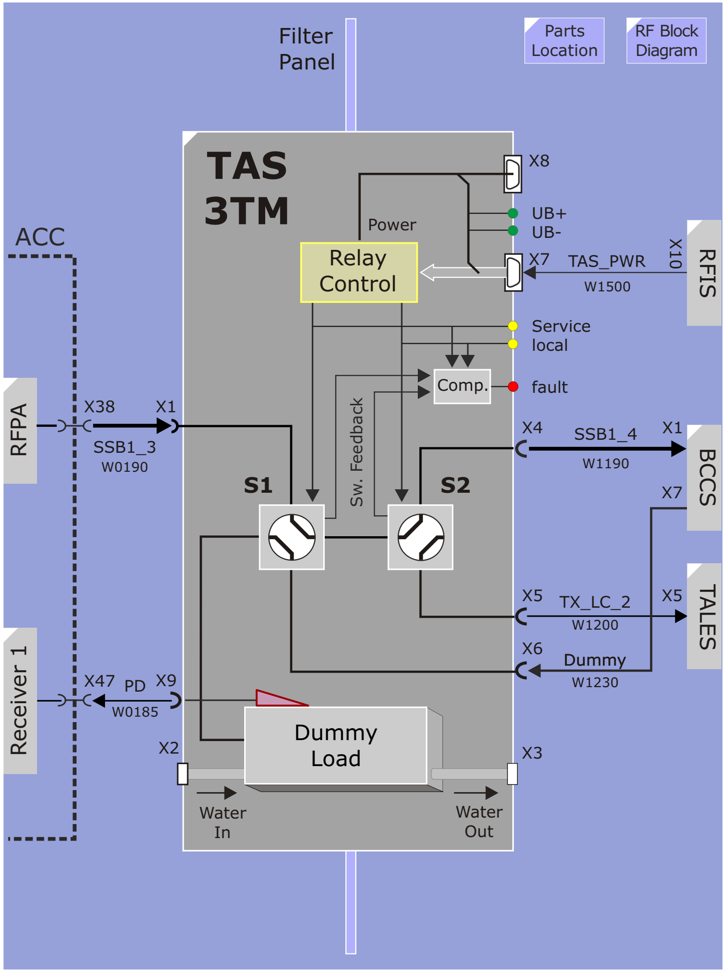
Relay Control

The switches are actuated with DC relays operating at 15 volts. The supply voltage of ±15 volts and the control signals for S1 and S2 are supplied by the RFIS.

LEDs

LED	Status	Description
UB+	ON	+15 V OK
UB-	ON	-15V OK
Service	ON OFF	S1 set RFPA to Dummy Imaging (RFPA to BCCS or TX local coil, depending on S2
Local	ON OFF	TX to local coil (via TALES) TX to body coil (via BCCS)
Fault	ON	Discrepancy between relay position and relay control signal. NOTE: **It is normal for this LED to blink when a relay is switched. A real fault condition is indicated only when this LED is permanently on.**

Figure 58 *TAS_3TM Block Diagram*



SAMI

The SAMI allows the use of the two RF amplifier over one common LC transmit path. The frequency duplex separates the two RFPA outputs while allowing a common connection to the LC transmit path.

Function

Decoupling Experiment

A dual-resonance Tx/Rx local coil is used. The broad band CORA RFPA generates x-nucleus magnetization and during the receiving of the x-nucleus signal the RFPA DORA applies a proton frequency RF pulse to the local coil in order to decouple the spectra and hence getting a better signal to noise ratio. See Figure 47 for a list of x-nucleus frequencies.

Figure 59 *Decoupling Experiment*

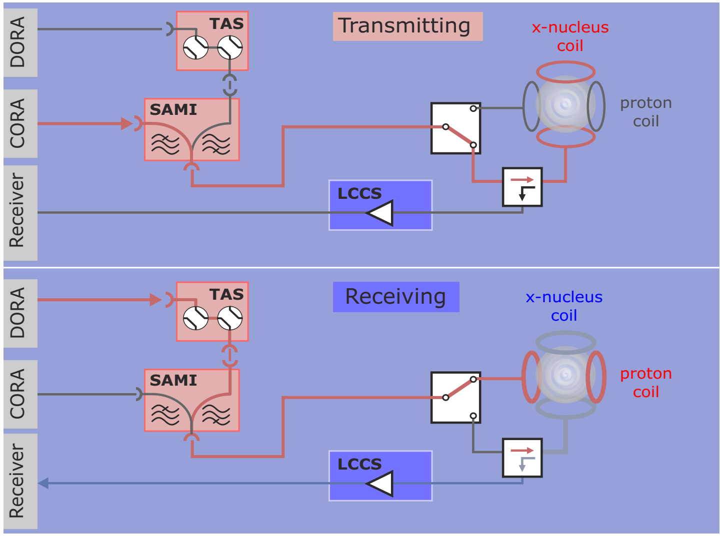
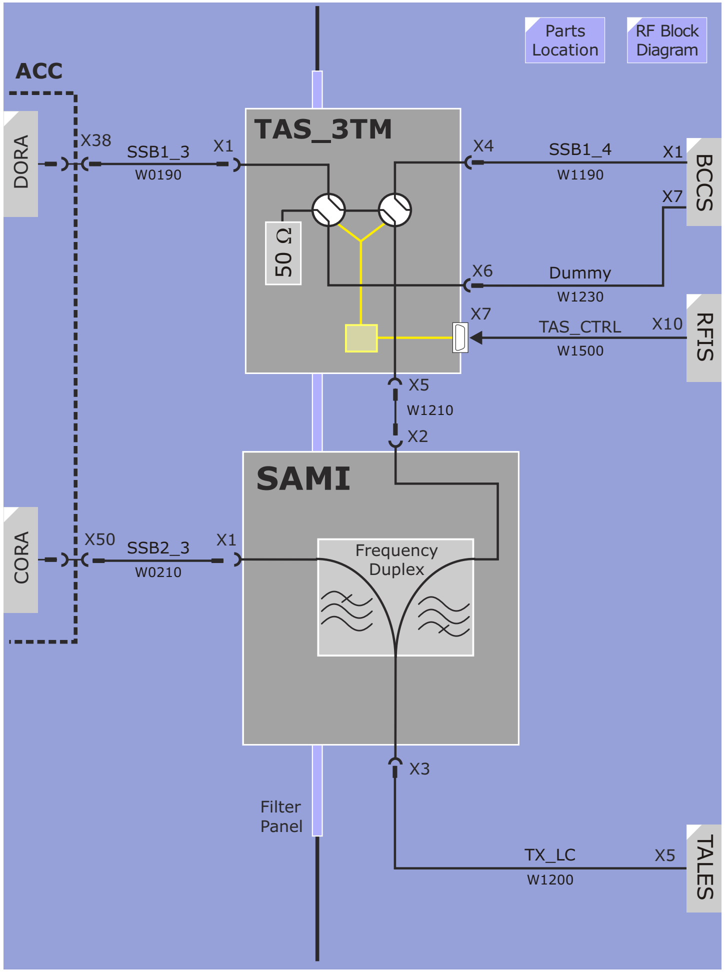


Figure 60 *SAMI Block Diagram*



BCCS_63_P

The Body Coil Channel Selector (BCCS) provides the necessary circuits to interface the RFPA to a circular polarized body coil. P = power: prepared for up to 35kW transmit power.

TX_Hybrid

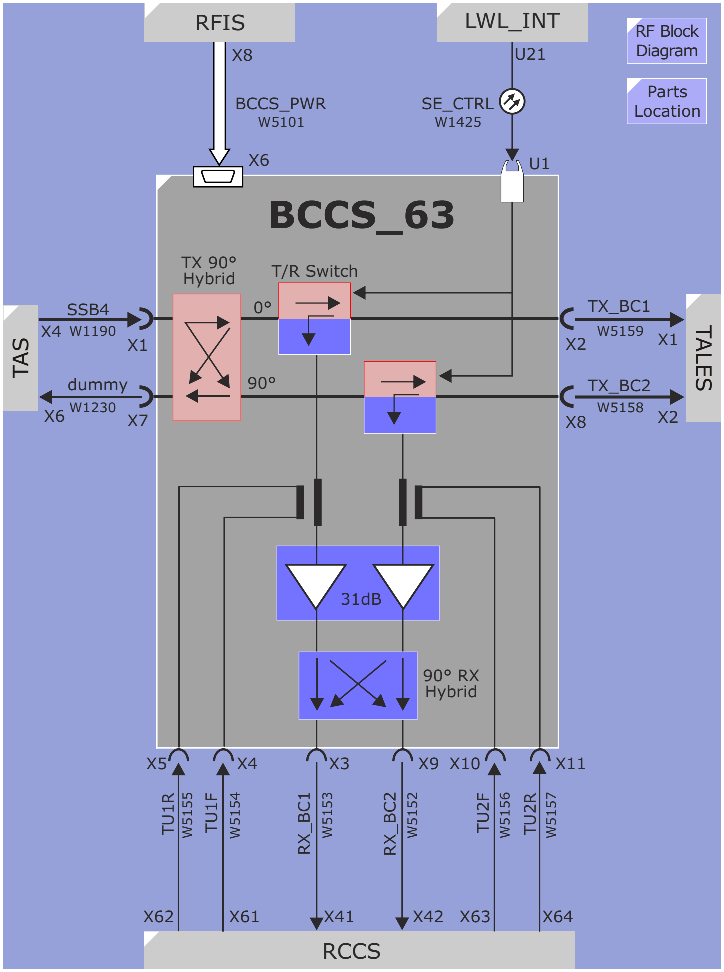
The TX_Hybrid produces a 90° phase shifting and power splitting of the transmit signal from the RFPA. The 90° phase shift is required by the Body Coil to develop a circular polarized B1 field. In order to achieve this with the highest efficiency, the following conditions need to be met:

- input ports X1 and X7 must be at 50 ohms
- the impedance at the output ports X2 and X8 must be balanced

The RFPA output provides a 50 ohm impedance at port X1 and port X7 is terminated by the 50 ohm dummy load in the TAS.

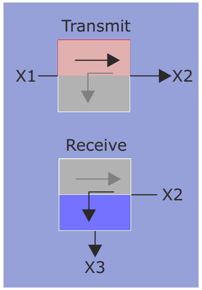
The output ports will be balanced when both Body Coil systems are tuned to the same frequency and the decoupling (transmission) is within specification.

Figure 61 *BCCS Block Diagram*



Transmit / Receive Switch

The T/R switch is required when imaging with the Body Coil. It is actively switched to provide a linear feed-through characteristic.



When transmitting **SE_CTRL** is active closing two diode switches. The first switch allows the RF signal to pass between X1 and X2 unimpeded. The path between X1 and X3 however is electrically isolated with a very high impedance preventing the therefore signal to pass through to X3. Even if the **SE_CTRL** signal is missing, the switches will close as soon as the RF transmit signal exceeds 0.7 V and the switch action just described will still work.

When receiving, the **SE_CTRL** is inactive (0V) and X2 is connected to X3.

Path X1 to X2 is electrically isolated as long as the MR signal does not exceed 0.7 V (it never will).

Directional Coupler

The directional coupler provides a port for tuning. A tune signal is applied alternatively to both the forward and reflected side of the directional coupler. The ratio of the amount of tune signal being coupled in the forward and reflected directions between the body coil and the amplifier is influenced by the impedance of the body coil.

Pre-amplifier

The narrow-band, low noise preamp has a fixed gain of 31dB.

RX_Hybrid

The MR signal received from the CP Body Coil, after being amplified, is recombined by the RX_Hybrid. The output is taken from X3. X9 is only used for the service procedures: Tuning Calibration, BC tests and BC tuning.

TALES

The Transmit Antenna Level Sensor (TALES) is a precision RMS RF voltmeter for measuring forward and reflected RF levels into the transmit coils (Body Coil or TX-local coil) for use in the SAR calculations.

Demodulators

The RF signal picked up over the directional couplers is demodulated and filtered producing a proportional dc voltage.

MUX

During transmission, the AMC selects each of the six values via a MUX with the select signals **MH_SEL**. The signal **CV** is output to the Modulator board where it is digitized and read in by the PCI_MON in the AMC for calculating the SAR values.

LEDs

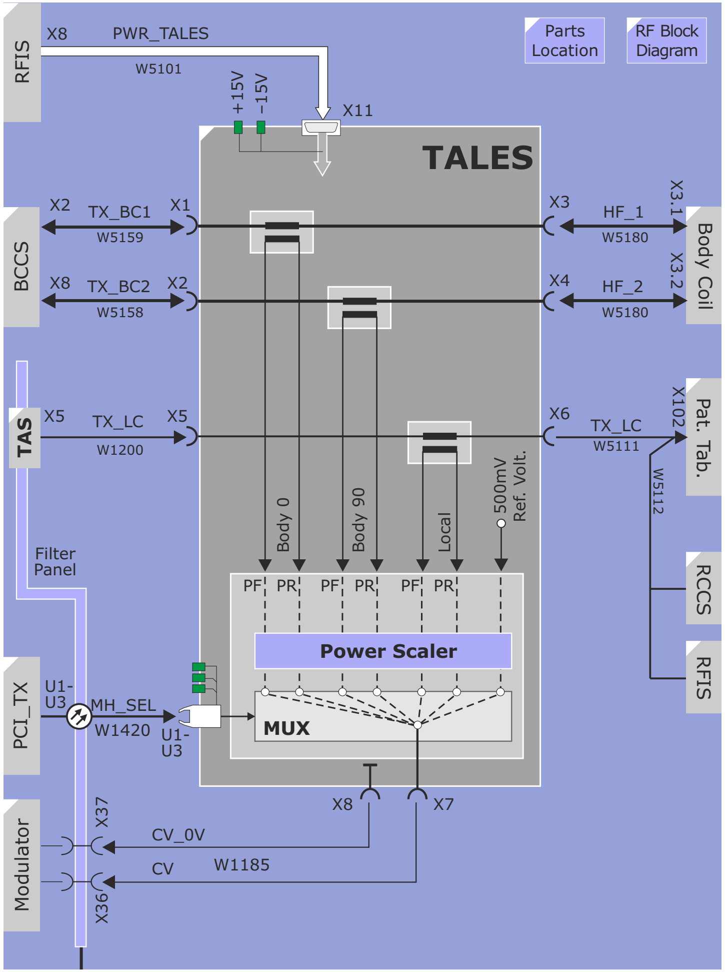
The LEDs display the selected signal being measured by the AMC.

Reference Voltage

In addition to the RF signal being measured, the TALES outputs a control dc reference voltage of 500mV. The reference is used to verify the accuracy of the signal coming from the TALES.

NOTE The TALES must be replaced every two years as part of the service maintenance. The old one will be sent back for re-calibration.

Figure 62 *TALES Block Diagram*



RCCS

The Receive Coil Channel Selector (RCCS), a 64 by 32 switch matrix with pre-amplification supporting 76 seamlessly integrated coil elements.

Switch Matrix

Local Coil Inputs

The Switch Matrix is constructed as a 64 by 32 array over which any one of the 64 local coil (LC) input channels can be switched to any of the 32 outputs channels. Due to the new Matrix Mode In contrast to the LCCS (Harmony/Symphony systems) it is no longer necessary, or possible, to combine two LC inputs to one output. Each input will be connected to one output only.

Body Coil Inputs

There are 8 Body Coil (BC) inputs, only 2 of which are being currently used. The 8 BC inputs are not switched through the 64 x 32 matrix but over a set of 8 addition switches directly to the first 8 outputs, i.e. BC1 to output 1, BC2 to output 2, etc. As a consequence each switched BC input makes the corresponding output unavailable for LC inputs. All unused LC and BC inputs are terminated with 50 ohm.

SGA Gain Switching

Each LC/BC input channel includes a switched gain amplifier (SGA) whose gain can be programmed to be either fixed low or high or dynamically switched during the sequence. The **RFAS_Low_Gain** signal is used for the dynamic gain switching.

Tuning-Multiplexer

The tuning signal **TTX** supplied by the Modulator board in the RFSU can be diverted via a multiplexer to one of 4 output paths all of which are going to the BCCS and are used for the Body Coil tune check procedure.

1-72 Multiplexer Test Path

The **TTX** signal can also be switched to any of the 72 input paths for testing purposes. The signal can be diverted over the Tuning MUX to a 1-72 multiplexer to any of the amplifier and Switch Matrix paths. In this way all the RCCS amplifiers and matrix nodes can be tested.

LC Voltage Supply & Monitoring

The RCCS supplies the local coils with power for their preamplifiers via a 10.5 V supply voltage. The voltage is fed to the LC over the cables connecting the LC connectors and the RCCS inputs. The circuit responsible for generating and regulating the 10.5 V from the 15 V supply is also able to switch the 10.5 V on and off. Each of the 64 supply channels is monitored and has a corresponding LED for indicating a shorted supply. If the LED lights, it indicates there is a short somewhere between the RCCS output pin and the Matrix or local coil.

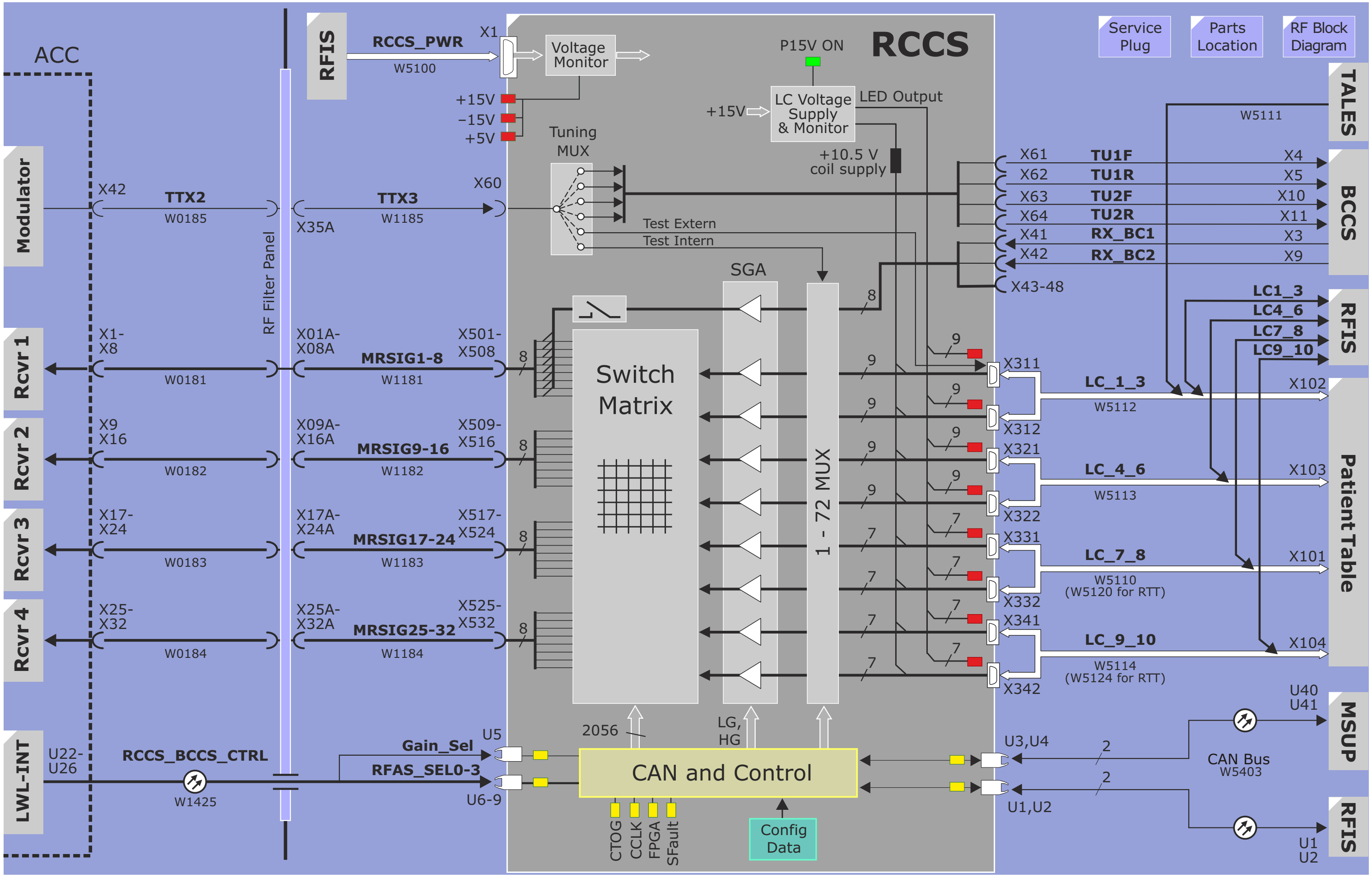
Settings

The setting of the Matrix for input to output switching, the setting of the Tuning MUX, the setting of the static or dynamic gain mode and high or low gain, and the setting of the Test Path MUX are made by the CAN and Control block. Up to 16 different settings can be stored in the CAN and Control section and selected dynamically via the setting group address signals **RFAS_SEL 0-3**.

The settings are stored at the MPCU as well. If a particular setting has been previously loaded into the RCCS, the MPCU does not have to retransmit it to the RCCS.

For whole body imaging, up to 13 of the 16 settings will be used for that purpose

Figure 63 *Receive Coil Channel Selector Block Diagram*



LEDs

As a rule of thumb the RCCS is in normal fault-free operation mode if no red LED is on and the one and only green LED is on.

LED	Description
Green LEDs	
P15V ON	On as long as the +15V are supplied to the RCCS.
Yellow LEDs	
All yellow LEDs are status LEDs, i.e. they define the status of a certain signal. They can be used for trouble shooting but their status is not a priori connected to a failure mode.	
FPGA	FPGA ready signal - turns on shortly after turning on of the DC supply for the RCCS. Indicates that all FPGAs are ready for operation.
CCLK	Control Clock - Is on if the internal RCCS Clock is active. Is off when the RCCS CAN-Bus is in sleep mode.
CTOG	Control Toggle - each state change of this LED indicates a data input into the RCCS FPGA
SFAULT	Sum Fault - This LED turns off whenever a sum voltage fault occurs i.e. whenever -15 V, +5 V, +15 V or +10.5 V are not OK.
CAN1, CAN2	Show the status of transmitting diode of the optical transmitter for the CAN-Bus interface.
GAIN	Shows the status of the RFAS_Low_Gain Control Signal. Light at this optical input turns all those SGA simultaneously to low gain, which are programmed for dynamic gain setting.
Red LEDs	
P5V, P15V, N15V	ON if the corresponding voltage is too low.
10.5 V LC Supply voltage	Each of the 64 LC inputs has an associated red LED labelled with the input number. If the 10.5 V LC Supply voltage is overloaded or shorted the monitor switches off the voltage for that channel and the corresponding red LED is enabled. The fault status is latched in order to catch sporadic or intermittent faults. To recover from this condition the RCCS must be reset which is achieved by rebooting the MR scanner.

Specifications

Value	Specification
Frequency range	15 to 125 MHz
Noise figure:	
low gain	max 10 dB
high gain	max 6 dB

Body Coil

Overview

The Body Coil (BC) generates the B1 field for excitation of the proton nuclei in the MR-experiment.

- Transmit-only mode - whereby the body coil transmits the excitation pulse and one or more local coils receive the MR echoes.
- Transmit/Receive mode - the body coil is additionally used for receiving the MR echo signal.

The primarily use of the Body Coil is for transmission of the excitation pulses and localizing imaging (scout scans, topology images) used for slice positioning.

The Avanto Body Coil is a circular polarized (CP) coil and based on the same high-pass birdcage design as used for the Symphony BC2. A principal advantage of the birdcage design is that the RF field amplitude drops very quickly outside the 500mm imaging volume thereby greatly reducing field ambiguity artefacts (aka third arm artefact) and also distributes the RF field over the length of the coil more uniformly.

In order to prevent the development of eddy currents on the conductive surfaces of the Body Coil, all large area conductive structures will be lacerated to suppress eddy currents.

Function

When the incoming RF signal is at the resonant frequency of the coil, the current flow through the coil resonator elements is inherently distributed between each resonator element over the end-rings. Being a CP coil, decoupling between resonator systems is an important issue. Strong coupling between the two resonator systems leads to high transmitter reference values and hence reduces the performance of the RF-transmit path. A procedure for checking and, if necessary, optimizing the decoupling is located in the Service Software platform under Tune Up / BC Tuning.

The Body Coil is a resonant device which transduces the current/voltage signals from the RF power amplifier to an electro-magnetic field. The magnetic component is designated as the B1 field.

When using local coils a detune circuit brings the body coil to off-resonance to prevent coupling with the local coils and thus absorbing any MR echo signal. For receive-only local coils the detuning is achieved dynamically (fast switching times). When using local coils capable of transmitting the body coil will be statically detuned. PIN diodes are the devices used to accomplish the detuning. A control voltage of -30 V is applied for dynamic detuning and a control voltage of approximately -440 V is used for static detuning. The detuning circuitry is integrated into the Body Coil.

The RF shield (Faraday shield) is laminated on the inside of the Gradient Coil and connected over the magnet shell to ground. The RF shield reduces B1 field losses into the gradient coil as well as serves to prevent possible disturbances.

Pickup Coils

Starting with SW VB13, the values measured by the pickup coils in the Body Coil are used to measure the coil power losses during tune-up step CPL and for every patient during the DICO test. The patient value is compared with the tune-up value and will be corrected in the case of deviations. The pickup coils are connected to the Receiver 2 in the RFSU, PF and PR, respectively. In the case, the customer has a 32x8 Tim system the pickup coils will not be used.

See Coil Power Loss description in the Tune Up section for further details.

Avanto Body Coil

Function

Fixed Impedance Matching

In contrast to previous body coils the Avanto body coil has been designed as a no-tune coil, that is, patient dependant impedance matching is no longer necessary. The impedance matching is set to a fixed value optimized for heavy loads where the power requirement is greatest.

As a consequence, in light load situations a very high reflection will occur. These reflections will be seen by the TALES and BCCS. In the BCCS most of this reflection will be directed over the hybrid to the dummy load located in the TAS. Assuming a properly functioning BCCS the RFPA should only see a maximum of 20% reflection in the worst case situation.

The maximum frequency shift as a result of a varying loading of the coil will be no greater than 200 kHz.

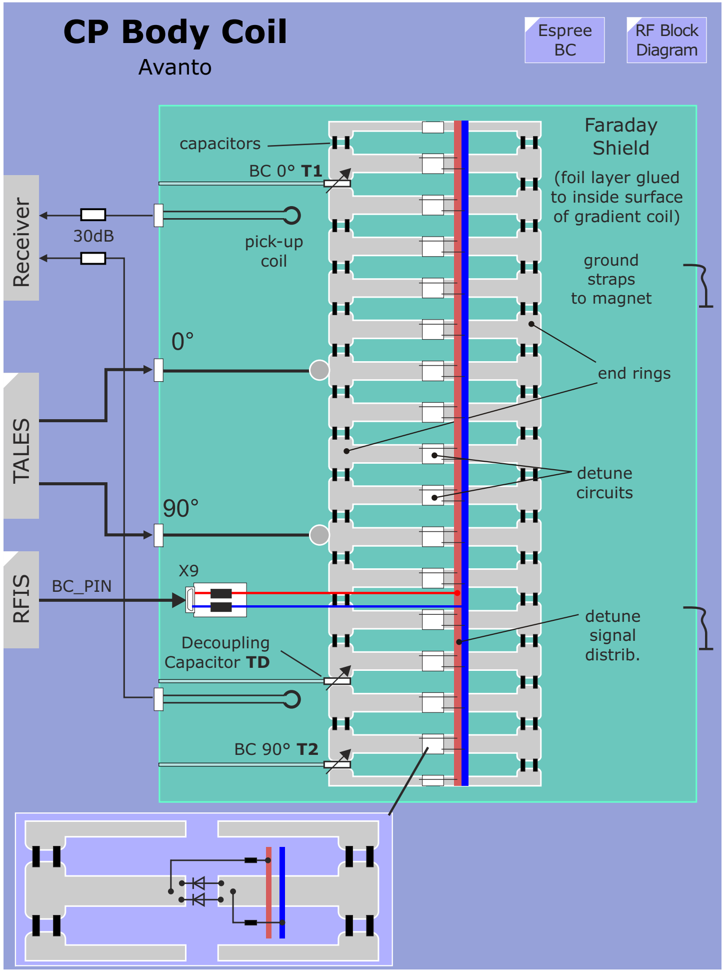
Static and Dynamic Detuning

PIN diodes, located on the Detune circuits, are used to both dynamically and statically detune the Body Coil. The detune voltages are described in the RFIS section.

Specifications

Value	Specification
center frequency	63.60 MHz
frequency tolerance	100 kHz
bandwidth	250 kHz
variation 1 within band of ±125 kHz	< 2.0 dB (peak-peak)
variation 2 within band of ±250 kHz	< 3.0 dB (peak-peak)
asymmetry1 (+125 kHz versus -125 kHz)	< 1.0 dB
asymmetry 2 (+250 kHz versus -250 kHz)	< 2.0 dB

Figure 64 *Avanto Body Coil Block*



Espree Body Coil AS 022

Function

Fixed Impedance Matching

The Espree body coil is a no-tune coil and does not require patient dependant impedance matching.

Static and Dynamic Detuning

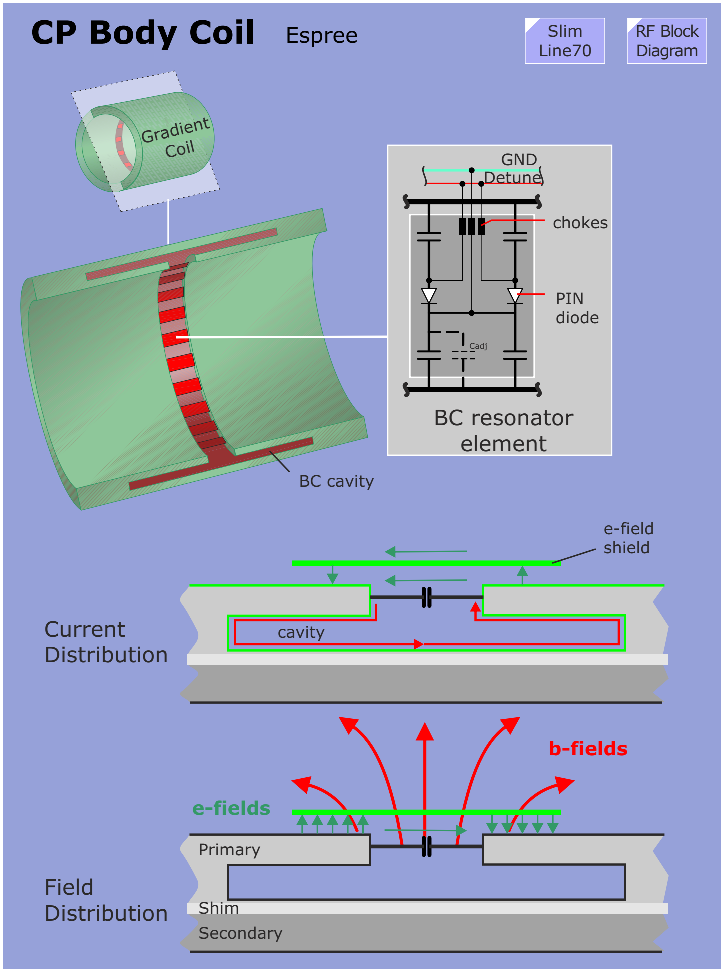
PIN diodes, located on the Resonator boards, are used to both dynamically and statically detune the Body Coil. The detune voltages are described in the RFIS section. The detune signals are fed to the 16 resonator boards over a ring band. When the diodes are closed (positive detune signal), the resonators are tuned. Opening the diodes with a reverse voltage opens the diodes and the resonators are detuned.

The resonator boards are moulded within the gradient coil and can not be removed or replaced.

Specifications

Value	Specification
center frequency	63.60 MHz
frequency tolerance	100 kHz
bandwidth	250 kHz
variation 1 within band of ±125 kHz	< 2.0 dB (peak-peak)
variation 2 within band of ±250 kHz	< 3.0 dB (peak-peak)
asymmetry1 (+125 kHz versus -125 kHz)	< 1.0 dB
asymmetry 2 (+250 kHz versus -250 kHz)	< 2.0 dB

Figure 65 *Body Coil Block Diagram*



Espree Body Coil Slim Line 70

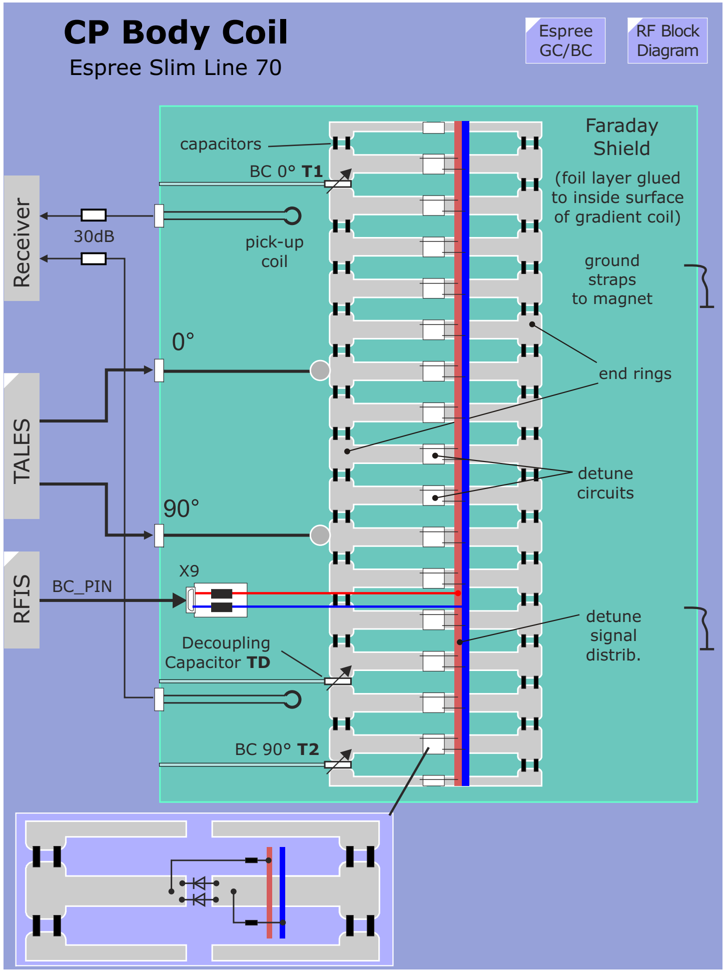
A new gradient and body coil was developed for the Espree systems called Slim 70. The Body Coil design is the same as the Avanto Body coil, a high-pass bird cage with adjustable capacitors for the two body coil systems and a decoupling.

This coil was put into production in August 2005 and was slowly phased into the assembly line towards then end of September 2005. From the end of September all systems were equipped with the Slim 70 coils.

Function

The same as the Avanto coil

Figure 66 *Body Coil Block Diagram*



RF Infra Structure (RFIS)

The RF InfraStructure (RFIS) contains the electronics providing:

- control signals for the dynamic and static detuning PIN diodes in the both the matrix and local coils and the Body Coil
- the detection and recognition of the connected matrix and local coils

The RFIS is built in a modular fashion consisting of a main motherboard and functional plug-in PCBs.

Figure 67 *RFIS Location*

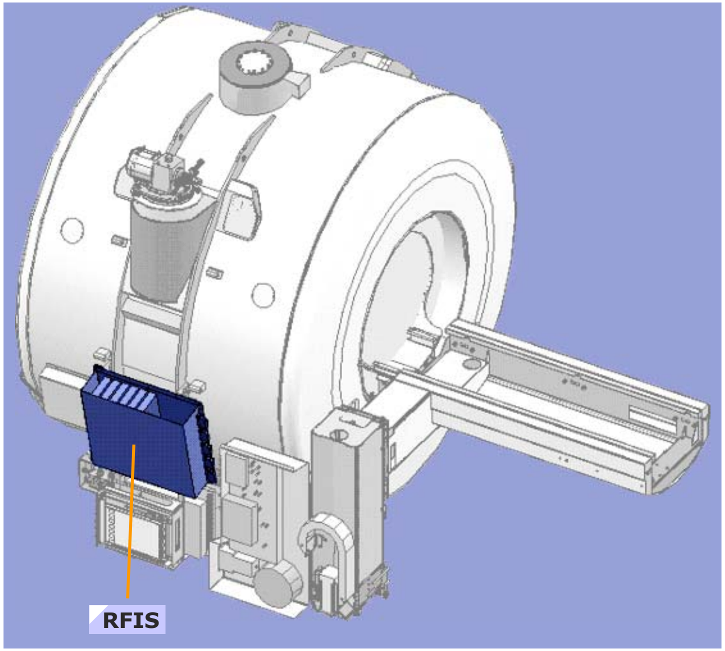


Figure 68 *RFIS Assembly*

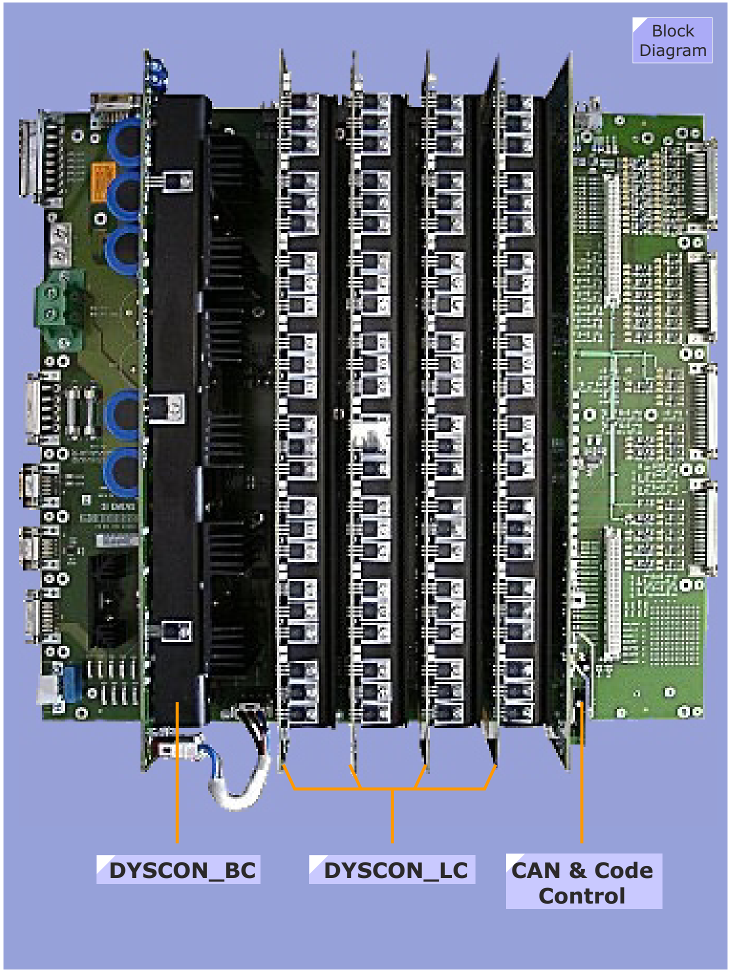
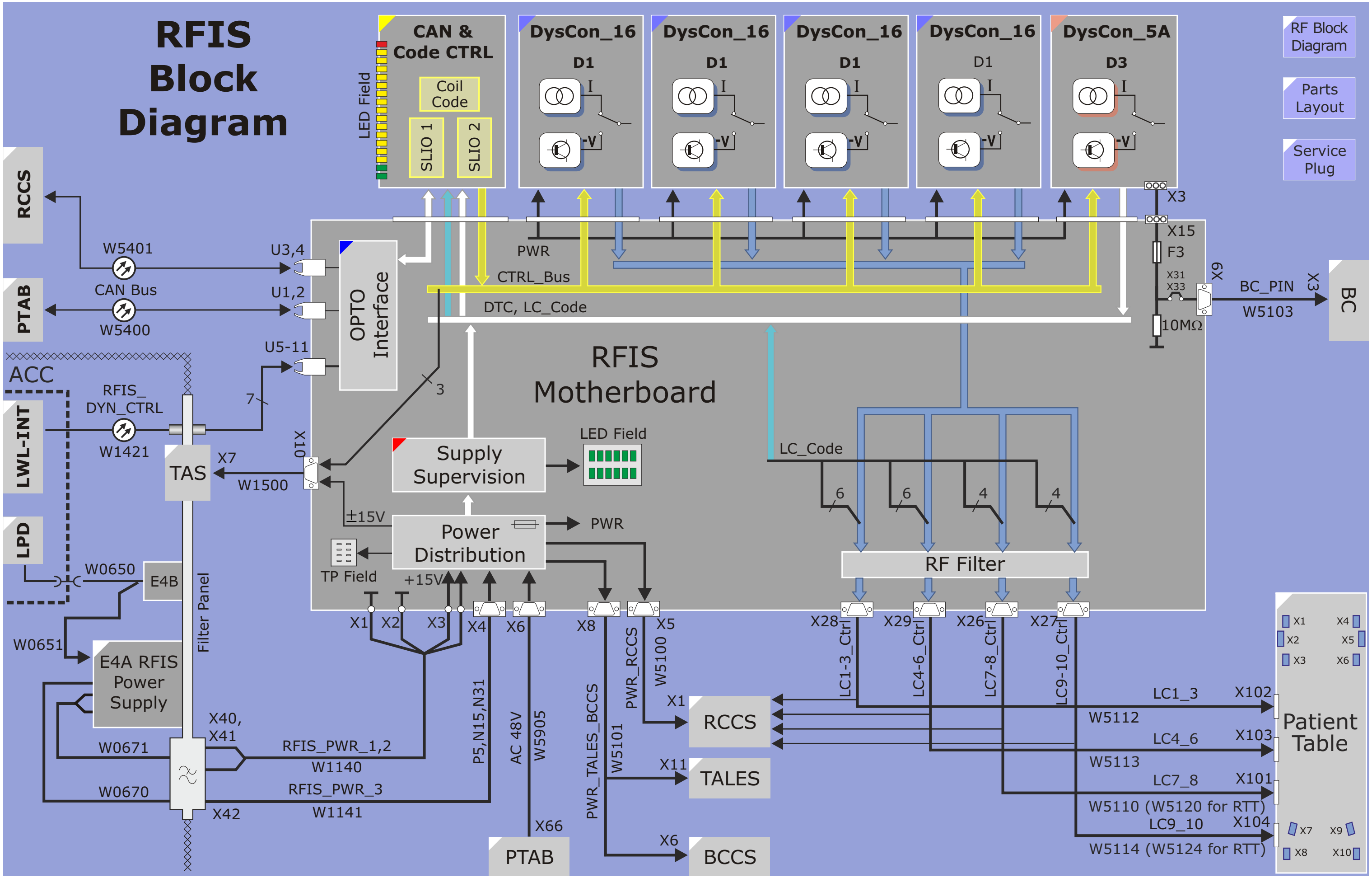


Figure 69 *RFIS Block Diagram*



Motherboard

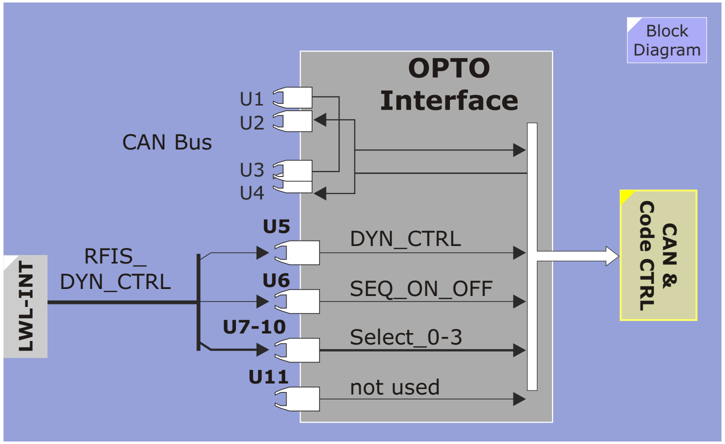
The Motherboard provides a common interface to the periphery and the functional plug-in PCBs.

OPTO Interface

The OPTO Interface converts incoming optical signals into electrical and vice versa. The following are the FO signals coming in and going out from the RFIS:

- DYN_CTRL - indicates the transmit or receive mode
- Seq_On_Off - signal for deactivating all PIN diode signals when no sequence is running (to prevent temp increases)
- Select 0-3 - select signals for the selection of the desired Mode- Settings (1 of 16)

Figure 70 *RFIS OPTO Interface*



LEDs

Each of the voltage monitors have an associated LED which when on indicates the voltage is present and within the monitored tolerances.

Power Distribution

This block is responsible for distributing the various operating voltages to the RF components within the RF room.

Jumpers

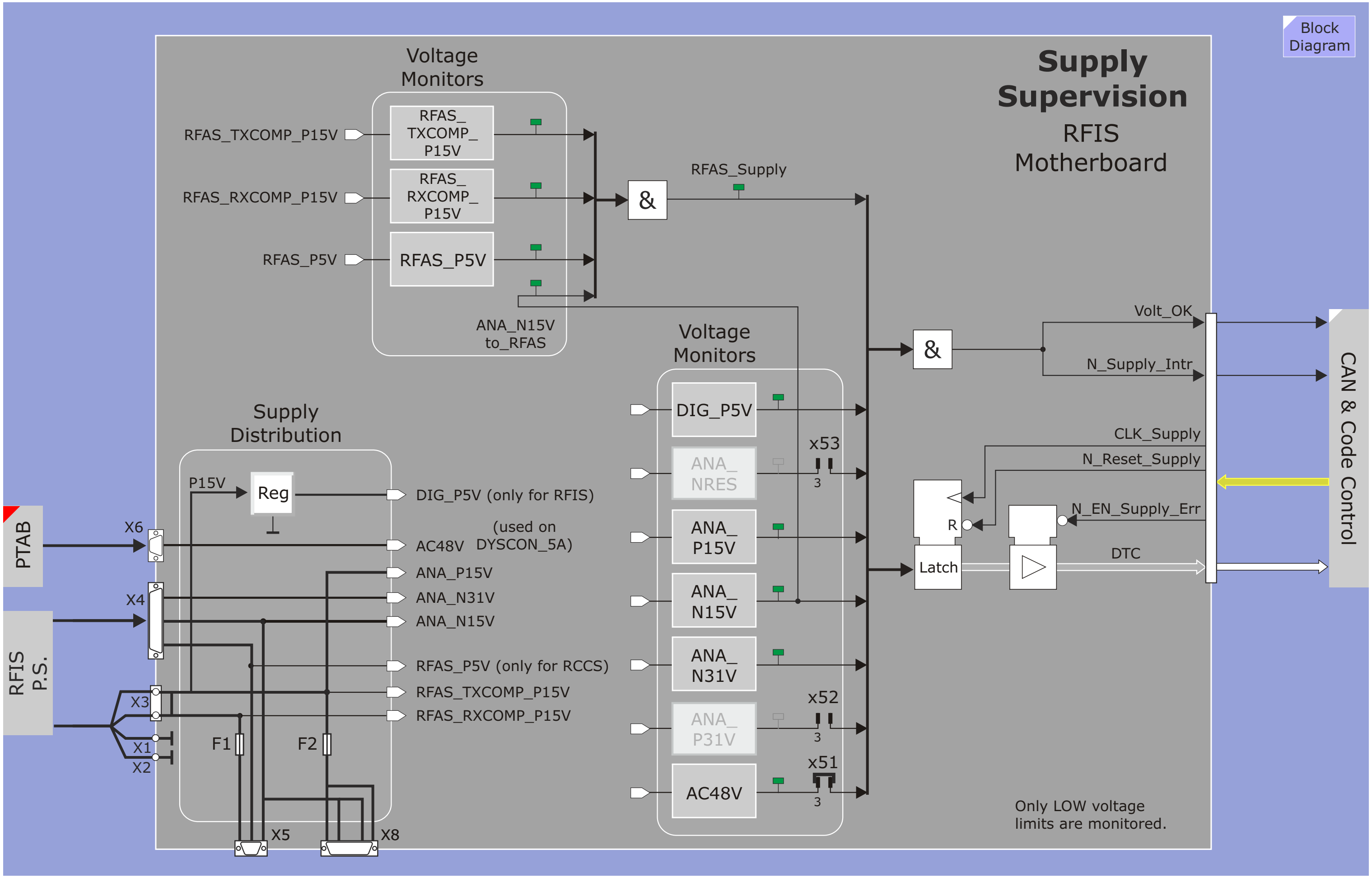
Jumper	Pins	Description
x51	2-3	AC48 monitoring (enabled)
x52	1-2	ANA_P31V monitoring (not enabled)
x53	1-2	reserved voltage monitor (not enabled)

Supply Supervision

The supply voltages for all the units being supplied by the RFIS are monitored here. The status of the voltages is displayed via LEDs. In the event of a voltage failure an **N_Supply_Int** interrupt is generated and passed on to the AMC via the CAN and Code Control plug-in module.

Voltage	Use	Monitored Threshold
P5V	RCCS	4,25 V ±5%
P15V	RFIS and all RF components	13,46 V ±5%
P15V TXComp	TAS, SAMI, TALES, BCCS, Pickup MUX	13,46 V ±5%
P15V RXComp	RCCS	13,46 V ±5%
N15V	RFIS and all RF components	- 13,46 V ±5%
N31V	RFIS	- 27,48 V ±5%
AC48V	RFIS	37 VAC ±3V

Figure 71 *RFIS Supply Supervision Diagram*



DYSCON_5A Module

This module serves to control the detuning PIN diodes in the Body Coil for dynamic and static detuning.

Dynamic Detuning

The Switch and Monitor block provides output switching of the dynamic detuning supply levels of +12V@5 A or -31V for tuning and detuning the Body Coil respectively via the **BC_PIN_CTRL** signal.

Static Detuning

When using transmit- local coils the Body Coil will be statically detuned with a high voltage of approximately -450V being applied to the Body Coil PIN diodes for the duration of the use of the transmit local coil. The static detuning voltage is enabled with the **BC_Dyn_On_Static_Off**. See LED table for logic levels.

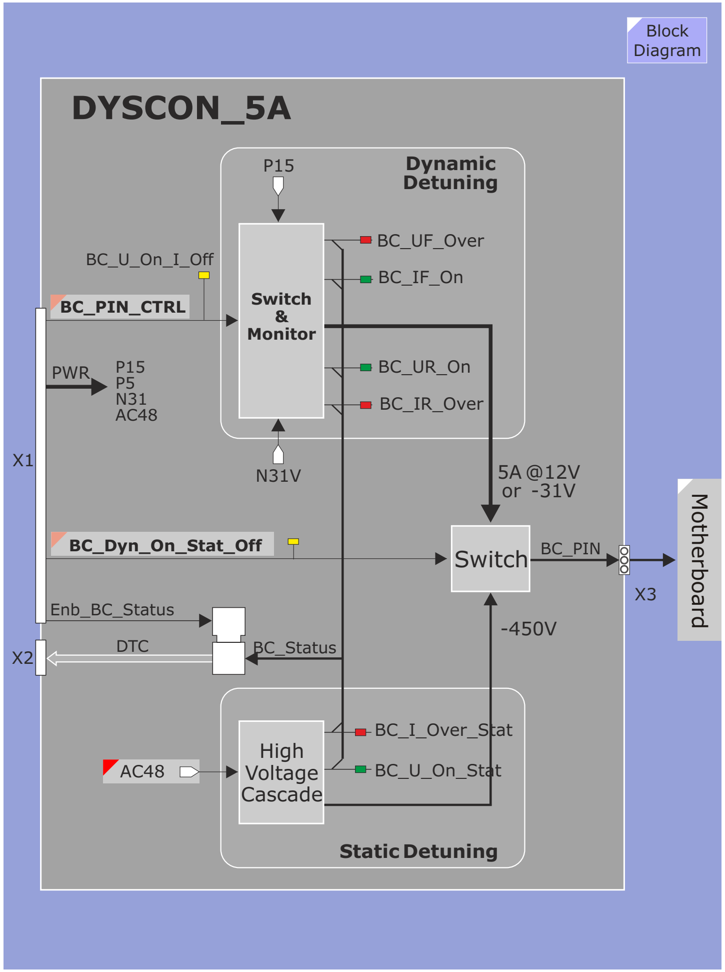
WARNING	**There are life threatening voltages present on the DYSCON_BC board. Exercise caution when servicing.**

Monitoring

The dynamic and static detune signal levels are monitored for proper levels. See LED description for explanations.

The CAN module reads in the status of the monitoring by applying the En_BC_Status signal. This is done at every system boot, a scanner reboot and when service tests are run.

Figure 72 *DYSCON_BC Block Diagram*



LEDs

LED	ON	OFF
BC_U_On_I_Off	-31V applied to PIN diodes, detuning the coil	+15V@5A is applied to the PIN diodes, tuning the coil
BC_Dyn_On_Stat_Off	BC dynamically detuned	BC statically detuned (-450V applied)
BC_UF_OVR	dynamic current source at max voltage (e.g. a break in the cable)	voltage level of current source is ok
BC_IF_ON	dynamic current output level is ok	dynamic current output level is too low
BC_UR_ON	reverse voltage ok	reverse voltage too low
BC_IR_OVR	too much current in reverse mode	current level in reverse mode ok
BC_I_OVR_STAT	current by static reverse voltage too high	current level in reverse mode ok
BC_U_ON_STAT	Reverse voltage level ok	reverse voltage too low

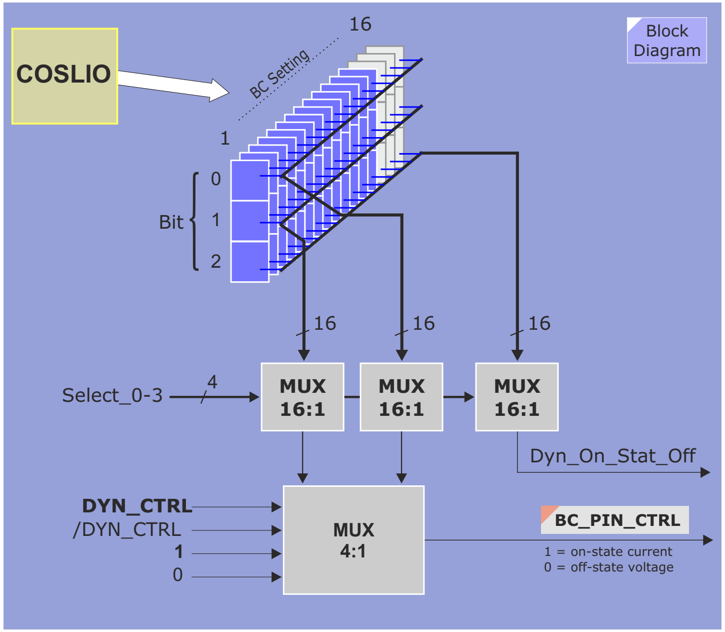
BC Settings

The BC_PIN_CTRL and Dyn_On_Stat_Off signals are generated in the FPGA on the CAN Module according to the circuitry shown in Figure 73. The circuit contains a mode table consisting of a 3 x 16 matrix. The COSLIO receives the values from NUMARIS and writes these into the mode table. Each bit-layer of the table is input to a 16:1 MUX. The dynamic control signals **Select 0-3** are used to address these 16:1 MUXs. Mode table bits 0 and 1 in turn address a 4:1 MUX applying to the output signal **BC_PIN_CTRL** one of the four signals: DYN_CTRL, DYN_CTRL inverted, 1, or 0.

The bit 2 layer is output via the third 16:1 MUX as **Dyn_On_Stat_Off**.

The 16 settings correspond to positions on the patient table, of which there are only 13, therefore the last 3 settings (designated by gray boxes in the graphic) are not required. The concept of this variable setting is to allow to control the Body Coil dynamically for Move During Scan examinations.

Figure 73 *BC Mode Table*



DYSCON_16 Plug-in Module

Each module contains 16 PIN diode switching circuits for the dynamic detuning of local coil elements. The signals can be programmed to be static during the sequence (i.e. the Body Coil is being used as receive coil) or to be dynamic, i.e. the Body Coil is used only for transmission and the local coils are used for reception. The signal programming is achieved on the CAN & Code Control module. The dynamic control signal

The RFIS Motherboard can accept up to 4 DYSCON_16 modules to control a total of 64 coil elements.

LEDs

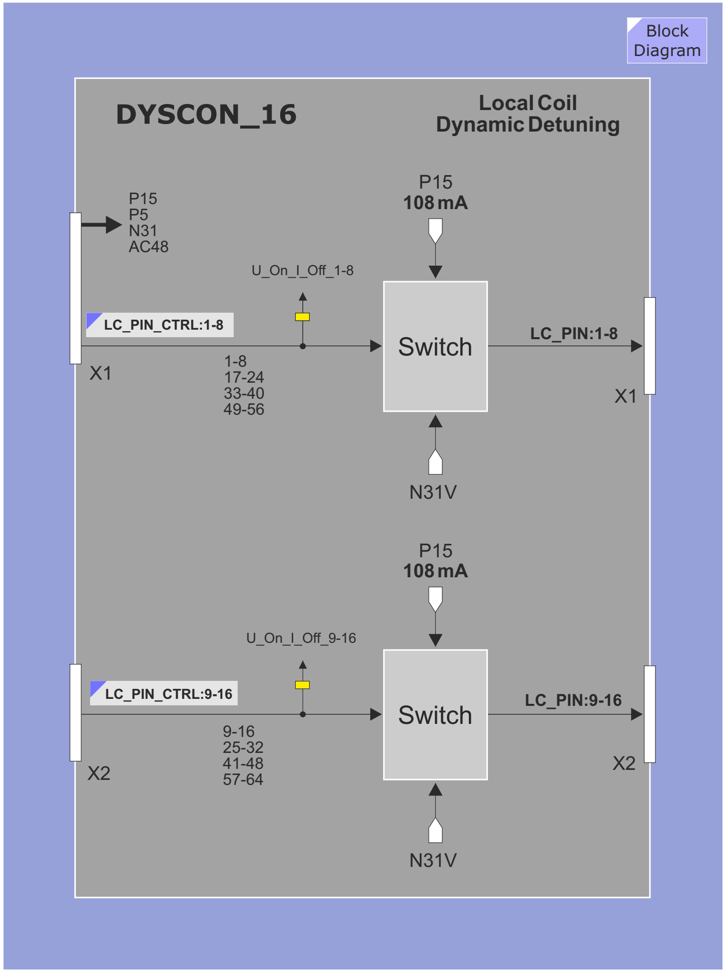
LED	Output	Coil
On	Voltage	tuned
Off	Current	detuned

This table only applies to SIEMENS coils and third party coils using the same de-tune concept as SIEMENS coils.

Monitoring

There is no monitoring circuitry for this module. The module can be tested with the service tests and the specially designed service plug. See Trouble Shooting Guide.

Figure 74 *DYSCON_LC Block Diagram*



LC Settings

The LC_PIN_CTRL signals are generated in the FPGA on the CAN Module according to the circuitry shown in . The circuit contains a mode table consisting of a 2 x 16 x 64 bit matrix. The COSLIO receives the values from NUMARIS and writes these into the mode table. Each bit-layer of the table is input to a 16:1 MUX. The dynamic control signals **Select 0-3** are used to address these 16:1 MUXs. Mode table bits 0 and 1 in turn address a 4:1 MUX applying to the output signal **LC_PIN_CTRL** one of the four signals: DYN_CTRL, DYN_CTRL inverted, 1, or 0.

The 16 settings correspond to positions on the patient table, of which there are only 13, therefore the last 3 LC Settings (designated by gray boxes in the graphic) are not required. The concept of this variable setting is to allow to control the matrix coils dynamically for Move During Scan examinations.

Figure 75 *Table Zones*

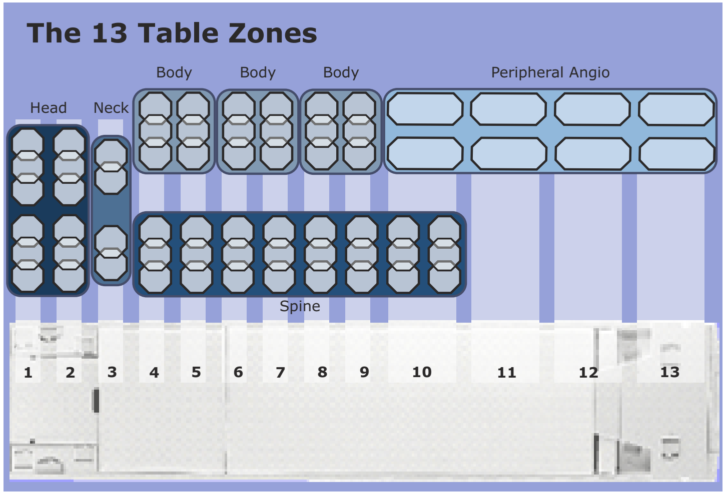
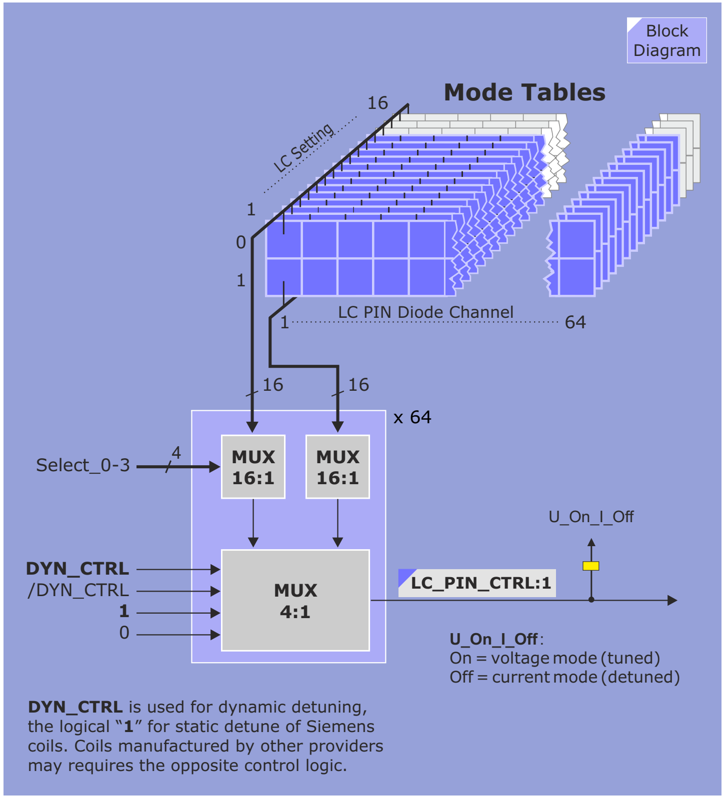


Figure 76 *LC Settings Memory*

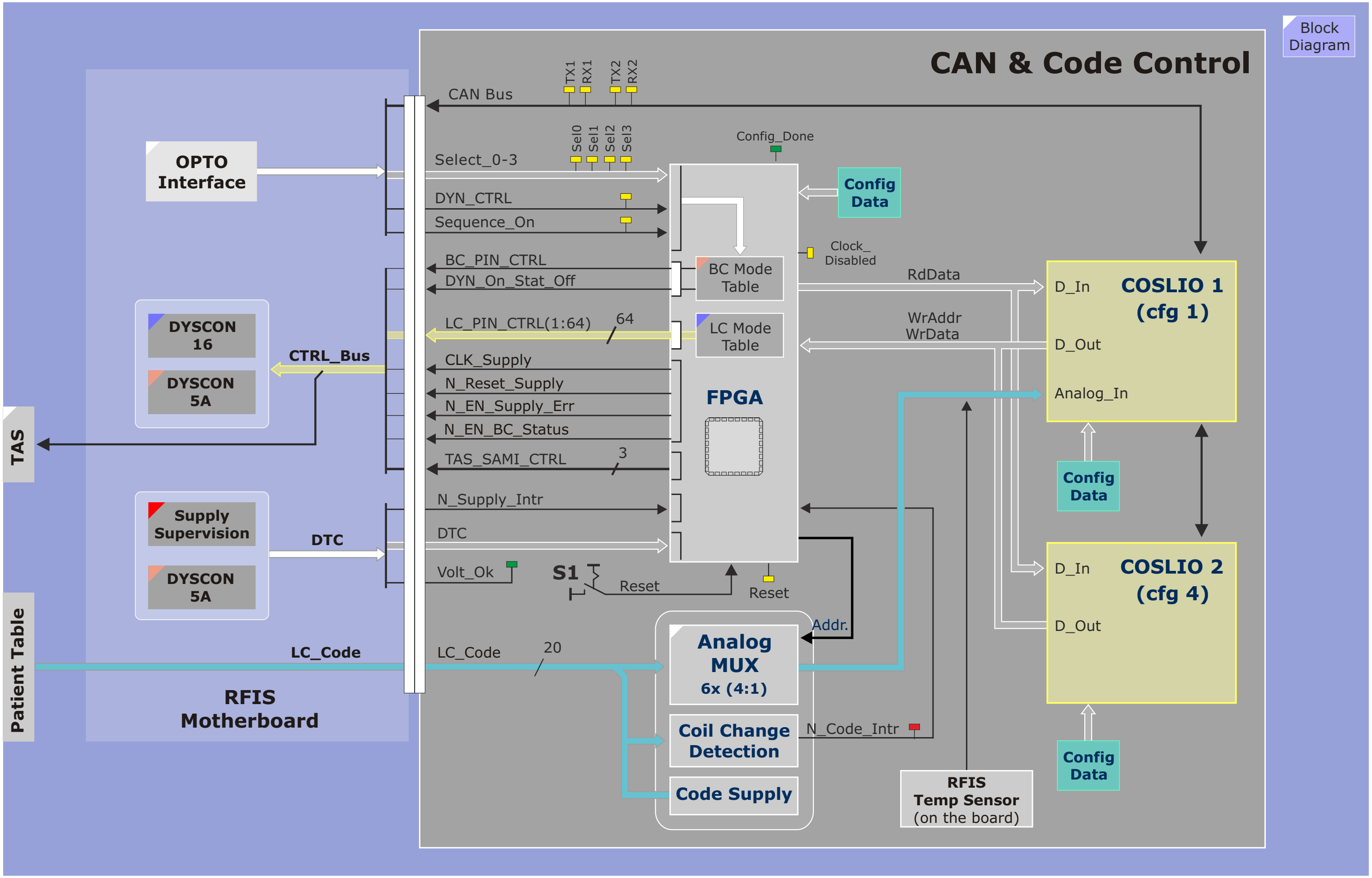


CAN & Code CTRL Module

This module fulfils the following functions:

- provides a CAN communications channel to system control for receiving control data and send feedback of monitoring status
- generate the PIN diode control and timing signals
- detect the connected local coils via their coil codes and report these to the System Control
- detect coil changes during a scan and report this to the System Control
- report supply status and RFIS temperature
- handling of sleep mode
- detect and report supply errors occurring during scan

Figure 77 *RFIS CAN & Code Control Module Block Diagram*



Coil Code Recognition

The coil section has two functions:

- Coil code detection
- Coil code change recognition

Coil Code Detection

To recognize the matrix or local coils that are connected a coil code recognition circuit has been realized using resistive coding. A 10V source with an internal impedance of 1.5 kΩ is terminated with resistors inside the coil connectors. These coding resistors have 13 defined values and since each coil connector is provided with two code lines a coil code, 2 to the power of 14 coil code combinations are possible. A list of the coil codes for the Matrix and other supported coil types can be found in the table below.

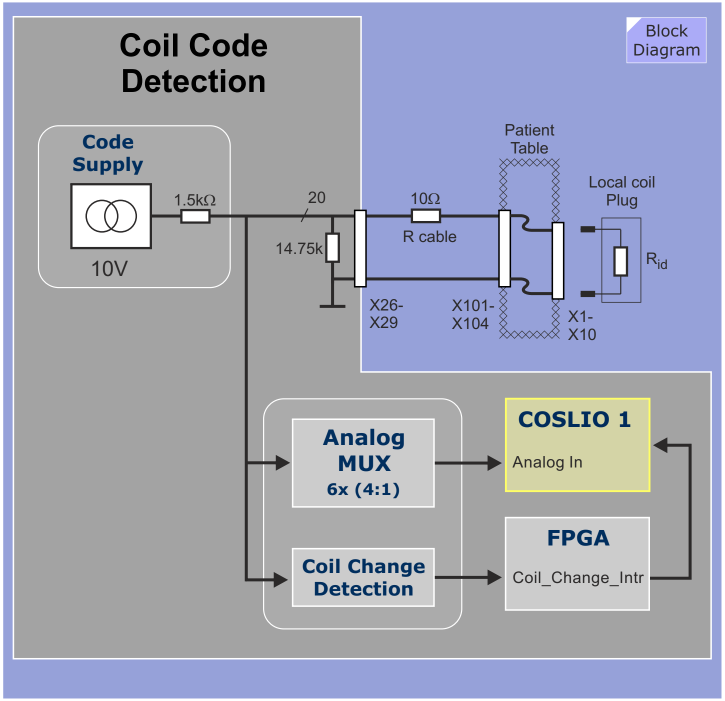
The code circuit is floating in respect to the rest of the coil electronics and thus uses a separate ground!

Coil Code Change

A current source generates a constant current that is fed to the coil connector. The local coils are equipped with one or more resistors connected to the 8 code signal lines. Where a resistor is found, a voltage drop is generated which is read and recognized by the CAN Module controller.

During the sequence, the coil code is continuously monitored. If it changes (e.g. the patient pulls a coil connector), an interrupt to the CAN Module will be generated. This will cause the sequence to be stopped.

Figure 78 *RFIS Coil Code Detection Diagram*



Coil Code Values

Coil code in Hex	Resistance NominaL	Voltage at MUX	Notes
0		0,314	short = error!
1	147	0,938	valid coil code values
2	273	1,564	
3	422	2,19	
4	601	2,816	
5	820	3,442	
6	1090	4,066	
7	1450	4,692	
8	1920	5,318	
9	2570	5,944	
A	3560	6,570	
B	5200	7,196	
C	8480	7,82	
D	18300	8,446	
E		9,072	no coils connected
F		9,698	open = error!

Matrix Coil Codes

Coil	Connector	Code
Head Matrix Upper	X6	5D
Head Matrix Lower	X3	AD
Neck Matrix Upper	X2	B7
Neck Matrix Lower	X2	37
Spine Matrix	X7	B1
Spine Matrix	X9	B2
Body Matrix 0°	X1	53
Body Matrix 180°	X10	57
PAA Matrix	X4, X8	51

Symphony and OEM Coil Codes

Short Name	Coil Name	Coil Code
31P, 1H, HL	Heart Liver (Spec.)	12, 16
EX	Extremity Coil	2b
DLL	Double Loop Array Left	2c
DLR	Double Loop Array Right	2d
UEF	MAI Upper Extremity Flex	32
LEF	MAI Lower Extremity Flex	33
WT	MAI Wrist Array	34
WR	Wrist Array	44
SH	Shoulder Array	4a
HB	MRIDC High Res.Head/Brain	4b
Shim	Shim Device	55
BR	CP Breast Array	58
FL	CP Flex Large	89
PH	FMRI 8 Channel Head Array	a4 aa
FLL	Flex Loop Large	bd
	16Ch_Body_A	c8, c9
	16Ch_Body_P	ca, cb
Ser._P	Service Plug	TX mode = cc RX mode = cd
FLS	Flex Loop Small	d9
BC	Integrated Body resonator	ff
FS	CP Flex Small	98
EN	Endorectal	9d

Matrix Coils

The MAGNETOM Avanto is the first system to use the newly designed set of receive-only Matrix coils which are part of the Tim system. Many of the Local Coils designed for use with the MAGNETOM Symphony system can also be used on the MAGNETOM Avanto. For more information click on the graphical below.

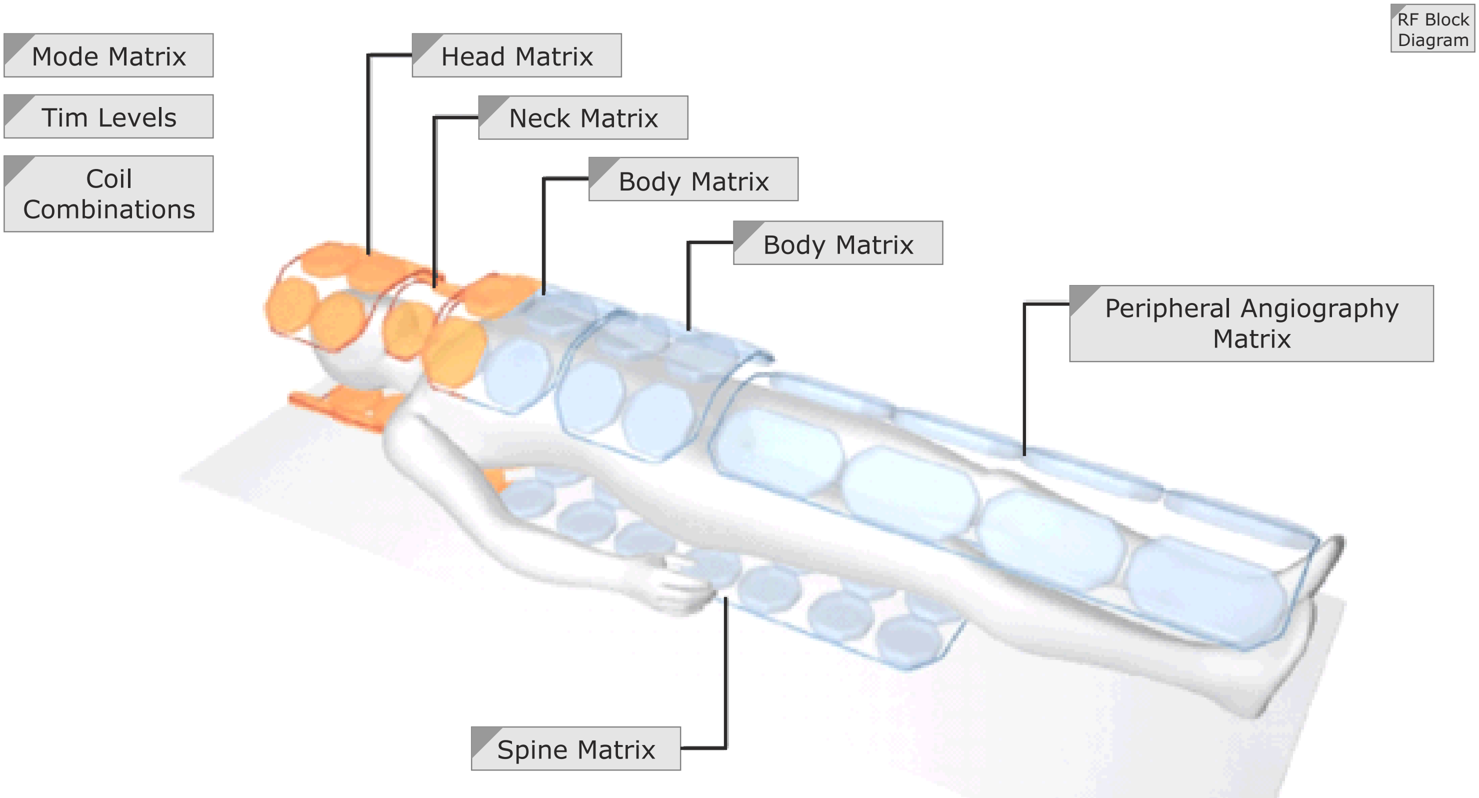


Figure 79 *Matrix Coils*

Matrix Coil Concept

The coil concept for the MAGNETOM Avanto consists of a set of receive-only coils which allow imaging of the whole body with parallel imaging capabilities in all directions. All coils can be applied simultaneously to the patient and subsets of elements of each coil can be selected as required for a particular examination region. The Matrix coil concept is the extension of the IPA concept of the MAGNETOM Symphony and Sonata to parallel imaging and whole body imaging. This new concept is called Total imaging matrix, or Tim, and includes the following individual coils:

Coil	Element Structure
Head Matrix	12 element coil, upper part removable
Neck Matrix	4 element coil, upper part removable
Spine Matrix	24 element coil
Body Matrix	6 element coil
PA Matrix	16 element coil combined internally to 8 CP elements (PA: Peripheral Angiography)

Technical Features

All Matrix coils are **pre-tuned** in the factory to a fixed load and no further tuning at the MR system is required. When the Body Coil is transmitting, all elements of the Matrix coils are detuned (switched off resonance).

Detuning and Safety Concept

The coil safety mechanisms built into all Matrix and Local Coils are designed to protect both patient and coil. The patient from uncomfortable RF burns and the coils from disintegration.

The safety mechanisms offer three safety levels: Each coil element is equipped with a detune circuit consisting of an inductor and a PIN diode which, when forward biased, creates a parallel resonance circuit in series with the coil element effectively opening the element and thus minimizing induced RF currents.

The second safety layer is a passive detune circuit which ensures proper detuning in case the PIN diode bias current should fail or the situation that the user forgets to connect a coil that is left on the Patient Table.

As a third safety layer a fuse is placed in every coil element that will blow as soon as the induced current reaches a dangerous level should the passive detune circuit fail.

Coil Recognition

The recognition of connected coils is made in the same way as in the Harmony/Symphony systems by means of analog coil codes realized with code resistors. This allows the Avanto coil control circuitry to recognize the Symphony Local coils as well.

Shock Indicators

Coils are exposed to heavy mechanical stress through daily usage and thus susceptible to defects through wear and tear as well as eventual misuse. Shock indicators are placed on each of the hard-cased coils, i.e. those coils with hard shells, to indicate whether a coil was exposed to excessive mechanical stress.

Amplifiers

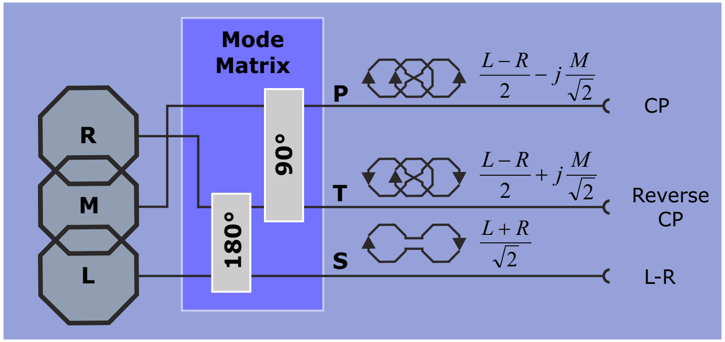
Each receive coil element is equipped with a low noise preamplifier to maximize signal-to-noise ratio.

Sheath Currents

RF traps have been included in the coils as well as in the connecting cables to suppress cable shield currents arising from the electrical field of the body coil. These currents, if not suppressed, will in turn create an RF field which will interfere with the MR experiment.

Mode Matrix

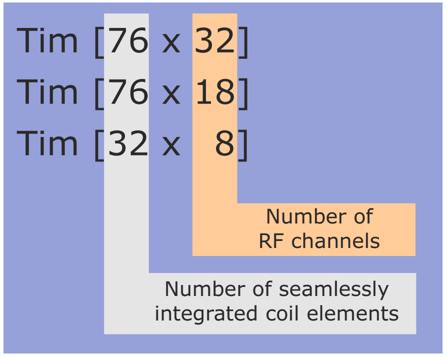
A key feature for all Matrix Coils, except the PA Matrix coil, is that they are not delivering signals from individual coil elements to the system, but combinations from two or three coil elements. This is done by feeding the signals of these elements into a so-called mode-matrix, where they are combined to two or three orthogonal (in the mathematical sense) signals. For example, three coil elements arranged in left-right direction of the patient are considered. The corresponding three signals are called L, M and R for left, middle and right, respectively. The first output signal of the mode-matrix, or *primary mode* (***P***), corresponds to the CP signal of a loop and butterfly antenna design which is commonly used as a CP coil element. The second output signal or *secondary mode* (***S***), is a combination of the signals from the left and right coil elements. The third output signal, or *tertiary mode* (***T***), corresponds to the reverse-CP signal, i.e. the signal of a CP element which is sensitive to the reverse CP components. Since the output signals of the mode-matrix are orthogonal, no information and no energy are lost.



The signals of the original coil elements could be recovered if needed. The reason and advantage for the use of mode signals instead of the original coil element signals is the more efficient use of receiver channels: If no parallel imaging acquisition (iPAT) is used, the primary mode is sufficient and only one instead of three receiver channels have to be used in this case.

Higher modes can be selected in order to obtain enhanced parallel imaging capability or to gain higher signal-to-noise ratio in the periphery of the field-of-view.

The Matrix Notation



76 - There are 10 coil plugs with 64 pins (4x8 + 4x6 + 2x4). The Spine Matrix coil has 24 elements, but has a built-in dynamic switch requiring therefore only 12 pins are required. Thus : 64 + 12 = 76 coil elements which can be seamlessly integrated into one single examination.

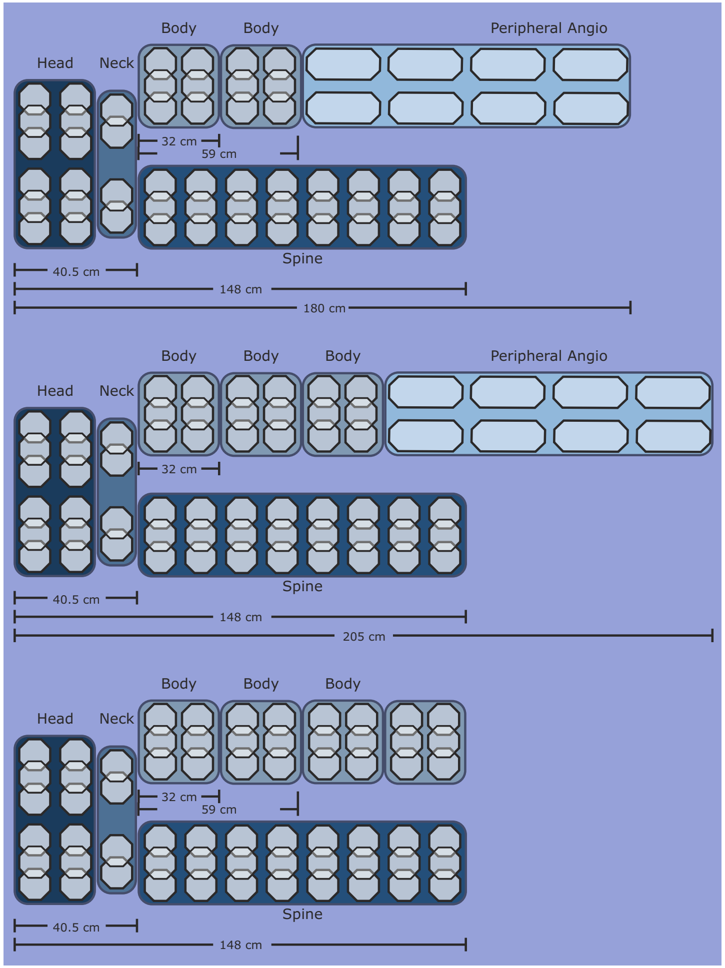
32 - is the number of effective coil elements in the CP mode: Head Matrix (4), Neck Matrix (2), Spine Matrix (8), Body Matrix (3x 2), PA Matrix (8) plus an additional 4-channel coil connected to one of the two Symphony-compatible coil connectors = 32 coil elements which can be seamlessly integrated into one single examination.

The last number is the number of independent RF receiver channels.

Flexibility

Another key feature of the Matrix Coil concept is that Matrix coils can be combined to increase coverage and allow whole body exams. Up to four identical Body Matrix coils can be connected in addition with other Matrix coils. The total coverage without repositioning the patient is 205 cm. Besides the Matrix coils other coils, e.g. the flex coils can be connected simultaneously and integrated into an examination.

Figure 80 *Some Matrix Coil Configurations*



Head Matrix Coil

The Head Matrix coil is a 12 element receive only coil. The 12 elements are arranged in two rings of 6 elements each around the head - one ring covers the crown of the head and the other the base of the head. For positioning the patient, the upper part of the Head Matrix is completely removable. Therefore, 6 of these elements (first half of each ring) are in the lower part, and 6 elements (second half of each ring) are in the removable upper part. Both parts are connected by a cable to the system. There are no electrical contacts between the upper part and the lower part of the Head Matrix.

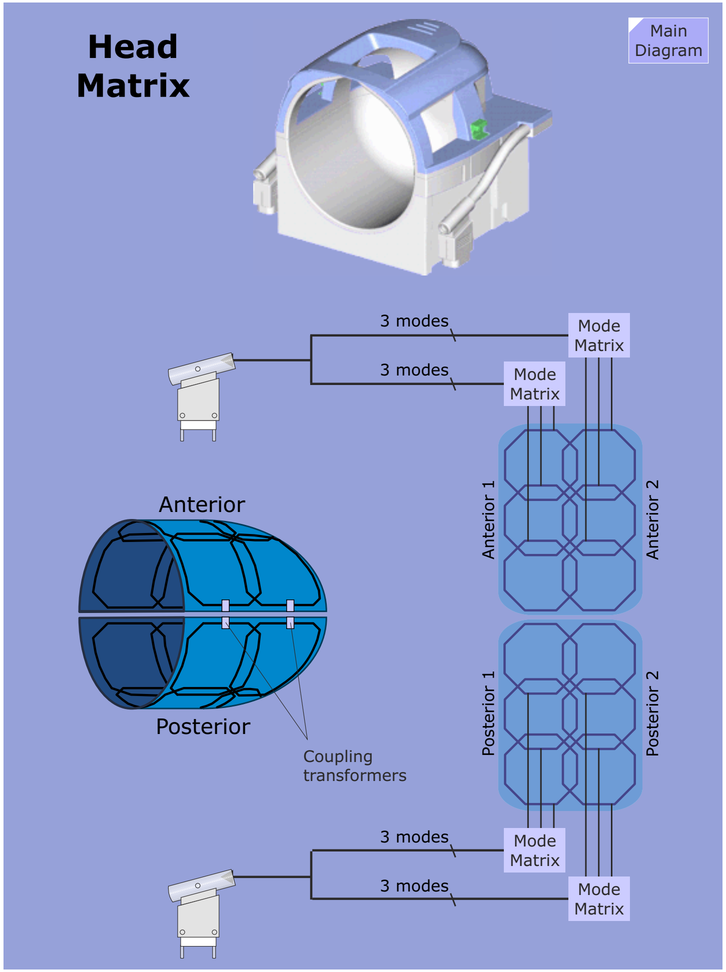
Two fixation devices can be used to immobilize the head. When imaging patients who are claustrophobic, the lower part of the Head Matrix can be used without the upper part. A mirror can be attached to the Head Matrix so that the patient can look outside the bore. Viewing to either the front or rear side of the magnet is supported.

The mode matrix implementation for this coil is to connect 3 adjacent elements of the two 6-element rings to a mode matrix. When only the primary modes are selected for examination, the coil behaves like a 4 element array coil: 2 elements in the anterior and in the posterior part, and 2 elements in the brain and in the feet-side section.

Applications include among others:

- Head examination
- MR-Angiography
- Combined Head/Neck examination

Figure 81 *Head Matrix Coil Construction*



Neck Matrix Coil

The Neck Matrix coil is a 4 element receive only coil. Two of these elements are in the lower part, and two are in the removable upper part. The upper part connects to the lower one.

When positioning the patient, the upper part is completely removable. The lower part of the coil can be used by itself. Mechanically, the Neck Matrix coils fits to the Head Matrix coil on one side and to the Spine Matrix coil on the other side.

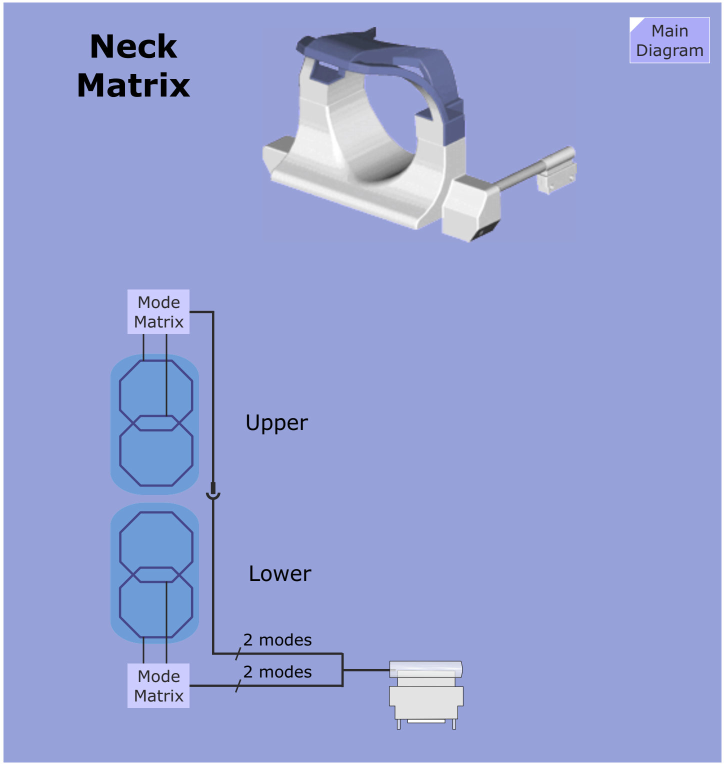
The mode matrix implementation for this coil is the CP mode as the primary one, and the reverse-CP mode as the secondary one. When only the primary mode is selected for examination, the coil behaves like a 2 element array coil with one upper and one lower element.

NOTE Although the Neck coil uses the same coil connector as the Symphony Local Coils, the Neck Matrix coil CANNOT be used on the Symphony system!

Applications include among others:

- Neck
- Larynx/Esophagus
- Cervical Spine
- MR Angiography
- Mediastinum

Figure 82 *Neck Matrix Coil*



Spine Matrix Coil

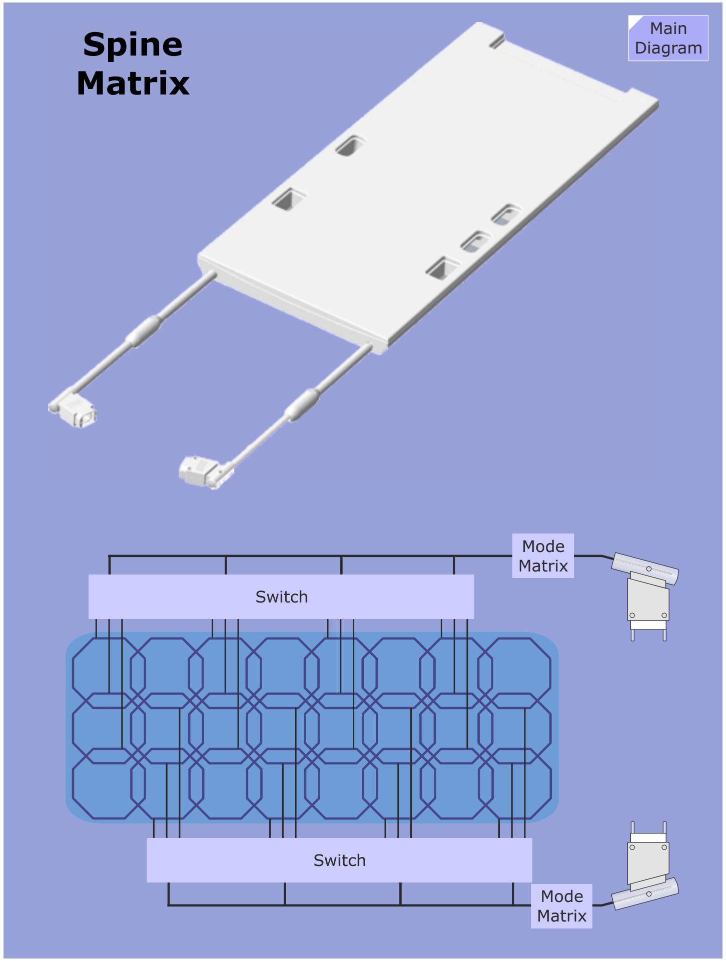
The Spine Matrix coil is a 24 element receive-only coil. The 24 elements are stacked in 8 clusters along the head-feed direction with each cluster consisting of 3 coil elements in left-right direction. Since not all of these 8 element clusters can be in the field-of-view at the same time, subsets of up to 4 adjacent element clusters out of the 8, or up to 12 out of the 24 elements can be selected for examination.

The mode matrix implementation for this coil is to connect the 3 elements of one element cluster to a mode matrix. When only the primary mode is selected for examination, the coil behaves like an 8 element CP array coil from which up to four adjacent CP elements can be selected.

Applications include among others:

- High resolution imaging of the whole spine
- Combination with various coils

Figure 83 *Spine Matrix Coil*



Body Matrix Coil

The Body Matrix coil is a six element receive only coil. The six elements are stacked in two clusters along the head-feed direction with each cluster consisting of three elements in left-right direction.

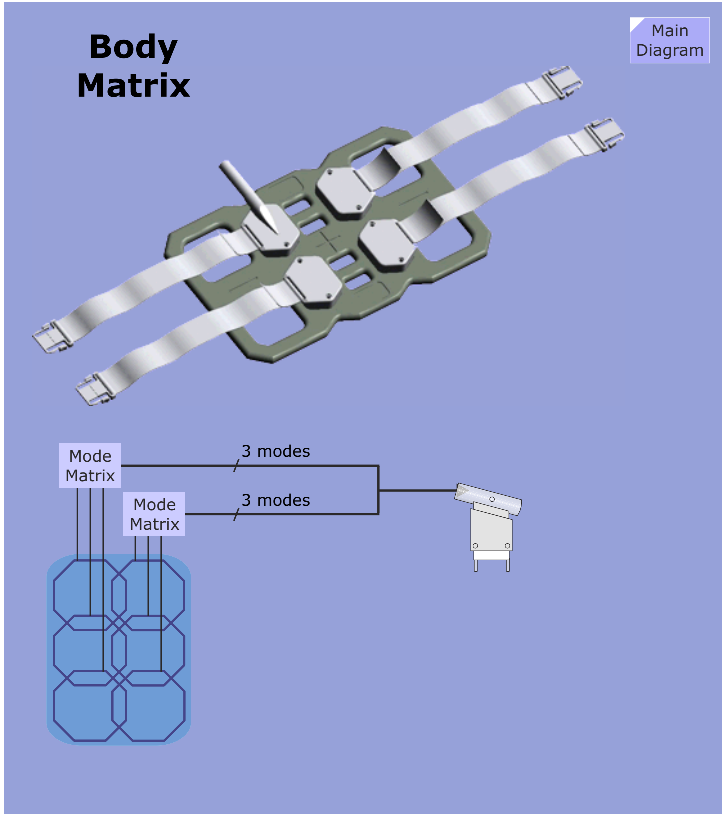
The mode matrix implementation for this coil is to connect the three elements of one element cluster to a mode matrix. When only the primary mode is selected for examination, the coil behaves like a two element CP array coil.

Up to four Body Matrix coils can be connected to the system simultaneously and mechanically attached to each other by Velcro strips. This assures equidistant spacing and thus uniform coil coverage.

The Body Matrix coil is similar to the 6-channel Body Array coil with several improvements.

- The connection to the system with one cable instead of two.
- A newly designed coil connector.
- The additional mode matrix.
- A slightly different coil size.
- A **direction detector** to detect the coil's orientation in the magnet. The last feature is needed because the coil can be rotated by 180° by the user with respect to the anterior-posterior direction, and in this case the CP mode and the reverse-CP mode are exchanged. The coil supplies a separate coil code for each direction: 53 for 0° direction (coil cable pointing toward magnet), code 57 for the opposite direction.
- High resolution imaging of thorax (including heart), abdomen and pelvis

Figure 84 *Body Matrix Coil*



Peripheral Angio Coil

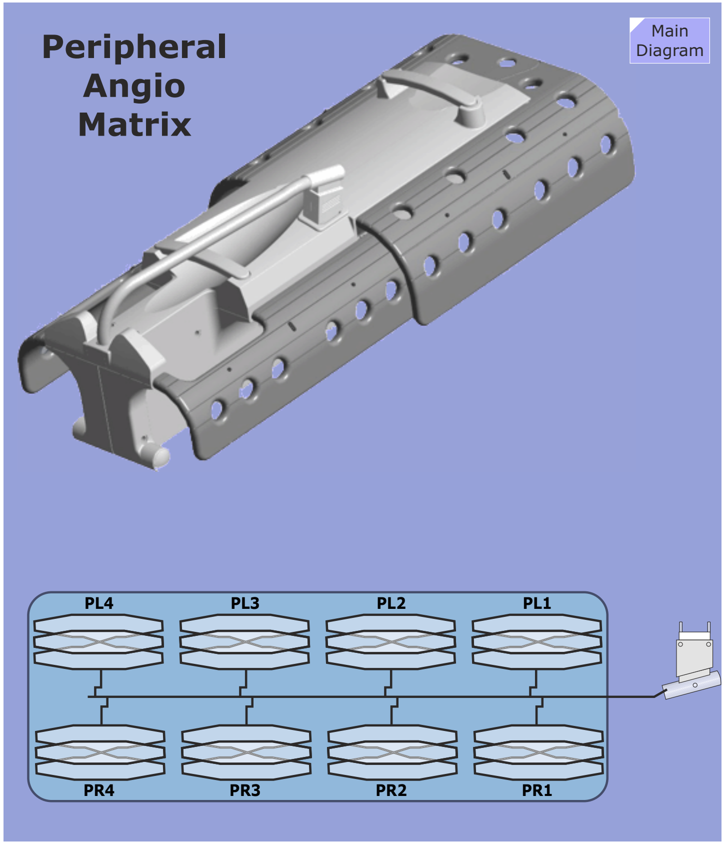
This coil is practically the same as the PAA coil for the Harmony/ Symphony. The connector and some internal adaptations for the Avanto coil interface were made.

This coil can be used in both directions for feet-first and head-first examinations.

Applications include:

- High resolution imaging of thorax (including. heart), abdomen and pelvis
- MR Angiography
- Combination with various coils

Figure 85 *Peripheral Angio Coil*



Matrix Coil Connectors

The next couple of pages provide the coil connector pinout diagrams and associated signal tables.

Figure 86 *Location of the Matrix and Local Coil connectors*

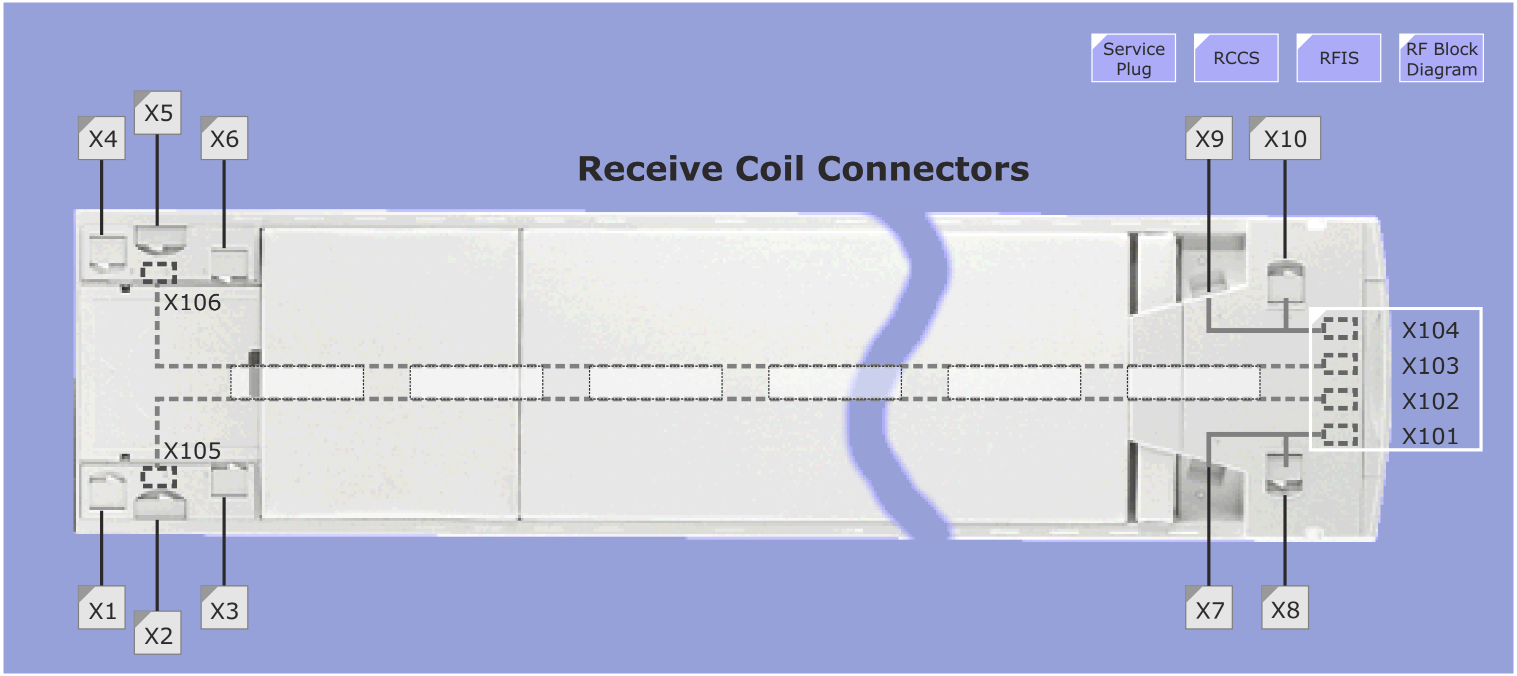
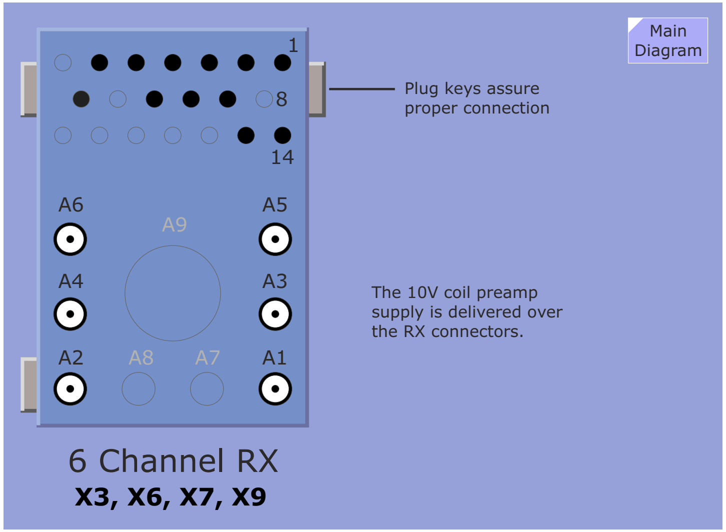


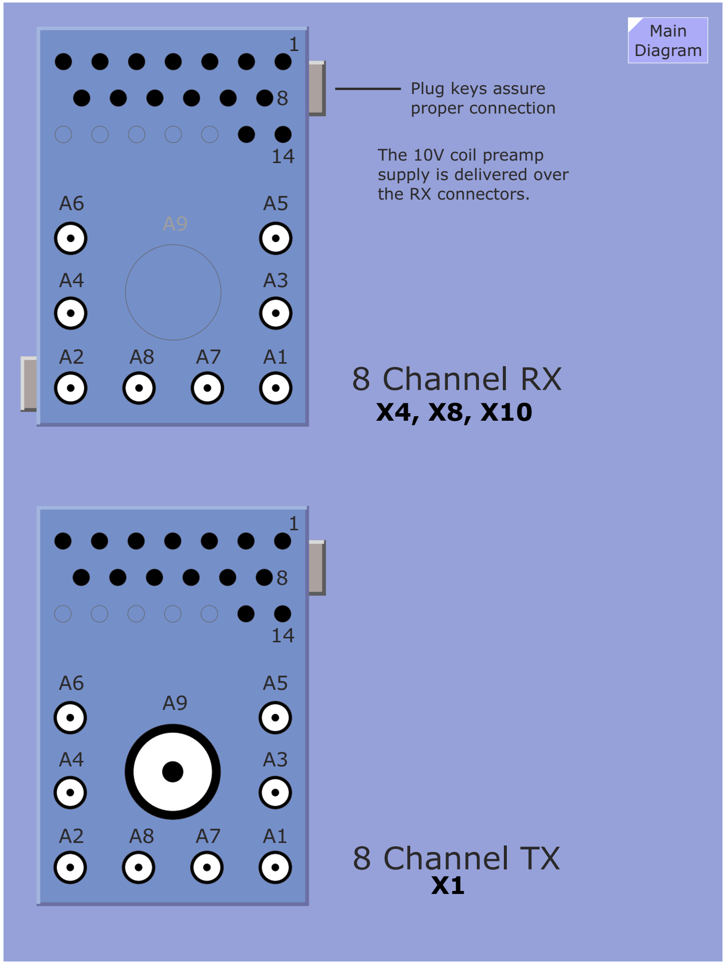
Figure 87 *Matrix Coil Connector - 6 Channel*



6-Channel Coil Plug Pin-out

Signal Name	Pin	Description
PIN1	1	I=100mA (to 12V) Reverse V = -30V
PIN2	2	I=100mA (to 12V) Reverse V = -30V
PIN3	3	I=100mA (to 12V) Reverse V = -30V
PIN4	4	I=100mA (to 12V) Reverse V = -30V
PIN5	5	I=100mA (to 12V) Reverse V = -30V
PIN6	6	I=100mA (to 12V) Reverse V = -30V
n.a.	7	n.a.
n.a.	8	n.a.
PIN GND 1	9	
PIN GND 2	10	
PIN GND 3	11	
n.a.	12	n.a.
Code1 / High Nibble	13	Code resistor *
Code2 / Low Nibble	14	Code resistor *
Code GND	15	
	16	
	17	
	18	
	19	
	20	
RX1 & 10V coil supply	A1	Rx Coax Connector
RX2 & 10V coil supply	A2	Rx Coax Connector
RX3 & 10V coil supply	A3	Rx Coax Connector
RX4 & 10V coil supply	A4	Rx Coax Connector
RX5 & 10V coil supply	A5	Rx Coax Connector
RX6 & 10V coil supply	A6	Rx Coax Connector
n.a.	A7	n.a.
n.a.	A8	n.a.
n.a.	A9	n.a.

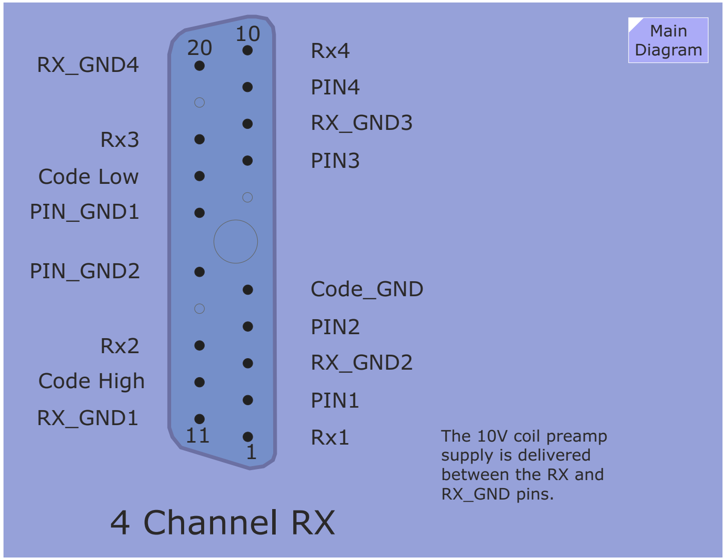
Figure 88 *Matrix Coil Connector - 8 Channel*



8-Channel Coil Plug Pin-out

Signal Name	Pin	Description
PIN1	1	I=100mA (to 12V) Reverse V = -30V
PIN2	2	I=100mA (to 12V) Reverse V = -30V
PIN3	3	I=100mA (to 12V) Reverse V = -30V
PIN4	4	I=100mA (to 12V) Reverse V = -30V
PIN5	5	I=100mA (to 12V) Reverse V = -30V
PIN6	6	I=100mA (to 12V) Reverse V = -30V
PIN7	7	I=100mA (to 12V) Reverse V = -30V
PIN8	8	I=100mA (to 12V) Reverse V = -30V
PIN GND 1	9	
PIN GND 2	10	
PIN GND 3	11	
PIN GND 4	12	
Code1 / High Nibble	13	Code resistor *
Code2 / Low Nibble	14	Code resistor *
Code GND	15	
	16	
	17	
	18	
	19	
	20	
RX1 & 10V coil supply	A1	Rx Coax Connector
RX2 & 10V coil supply	A2	Rx Coax Connector
RX3 & 10V coil supply	A3	Rx Coax Connector
RX4 & 10V coil supply	A4	Rx Coax Connector
RX5 & 10V coil supply	A5	Rx Coax Connector
RX6 & 10V coil supply	A6	Rx Coax Connector
RX7 & 10V coil supply	A7	Rx Coax Connector
RX8 & 10V coil supply	A8	Rx Coax Connector
TX	A9	Tx Coax Connector

Figure 89   *Matrix Coil Connector - 4 Channel*



This coil connector is compatible to the Symphony Local Coils. There are two such connectors on the Patient Table, neither of which, however, have a transmit pin. For this reason the transmit-receive local coils, such as the Tx/Rx CP Extremity coil, cannot be used on the Avanto.

4-Channel Coil Plug Pin-out

Signal Name	Pin	Description
PIN1	2	I=100mA (to 12V) Reverse V = -30V
PIN2	4	I=100mA (to 12V) Reverse V = -30V
PIN3	7	I=100mA (to 12V) Reverse V = -30V
PIN4	9	I=100mA (to 12V) Reverse V = -30V
PIN GND 1	16	
PIN GND 2	15	
Code1 / High Nibble	12	Code resistor *
Code2 / Low Nibble	17	Code resistor *
Code GND	5	
	19	
	14	
	6	
RX1 & 10V coil supply	1	Rx Coax Connector
RX2 & 10V coil supply	13	Rx Coax Connector
RX3 & 10V coil supply	18	Rx Coax Connector
RX4 & 10V coil supply	10	Rx Coax Connector
RX_GND1	11	Rx Coax Connector
RX_GND2	3	Rx Coax Connector
RX_GND3	8	Rx Coax Connector
RX_GND4	20	Rx Coax Connector

NOTE   The pins are not in numerical order in this table!

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Section

6

Patient Handling

Introduction

The AVANTO Patient Handling system is a newer development of the previous successful design of the MAGNETOM Harmony/ Symphony components. Several new features have been introduced to further increase the performance, such as the table scan range of 205 cm (average) vs. the 145 cm of previous systems, faster horizontal table drive speeds for Peripheral Angio applications, the support of Matrix coils and the Tim applications and a wireless Physiological Measurement Unit interface.

The Patient Handling consists of the following main components:

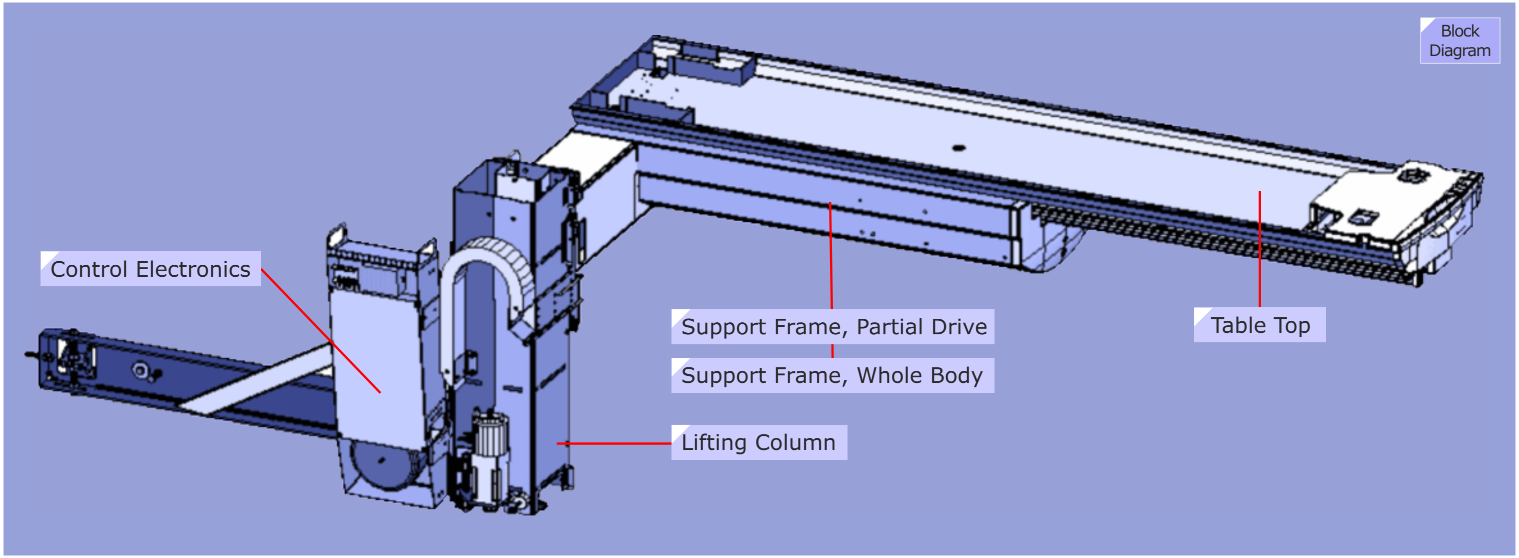
- **Basic Table** with fixed Table Top, available with 154 cm scan range or "Tim Whole Body Suite" with an enhanced range of 205 cm.
- **Trolley (option)** with Removable Table Top (RTT)
- **Physiological Measurement Unit** with wireless data transmission of ECG, Pulse and Respiratory-signals and connection possibility for external triggering. Additionally, a PMU display to be mounted at the Magnet front-left side is available.
- **Intercom System** for communicating with the patient

Patient Table

Overview

The Patient table is available as "Basic Table" for a 154 cm scan range or "Whole Body" option for a mean scan range of 205 cm (203 head first; 207 cm feet first). The "Whole Body" option is enabled by the "Tim Whole Body Suite" software license.

Figure 90 *Patient Table Assemblies: Mechanical View*



Lifting Column

General

The lifting column is a free standing construction with minimum overall height and a depth of just 230 mm. Nevertheless a "Basic Table" it is able to lift and support a Patient weight of up to 250 kg. If a Trolly (RTT) option is installed the maximum patient weight is 200 kg.

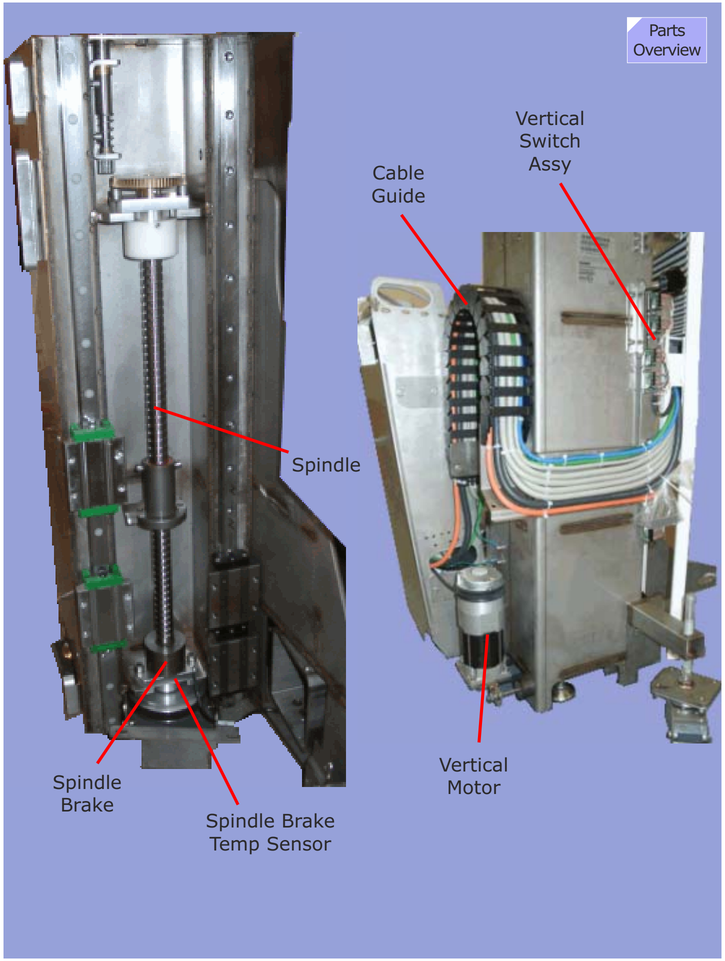
The Lifting column has a well-designed interface to the magnet that allows easy removal or reattachment of the whole table (e.g. to reduce transport dimensions in case of space limitations).

All components can be serviced from the Magnet front-side.

Main parts are:

- **Spindle Assembly** with ball bearing (to minimize mechanical wear) and a mechanical brake. The spindle and mechanical guide-rails are maintenance free.
- **AC-Synchronous motor** to drive the spindle via tooth belt. For safety reasons, the motor contains a second (electro-mechanical) brake (see also Drive control description).
- **Vertical Switch Assembly** to control vertical end positions and speed. For safety reasons mechanical end-stops are part of the vertical drive (see also Drive Control description).
- **Cable Guide -** including control- and RF-cables to the Table Top.

Figure 91 *Lifting Column Assembly*



Support Frame

The Support Frame consists of the following components:

- **MDSD** - a horizontal drive that consists of an AC-Synchronous motor with an integrated gear-box, position encoder and drive control electronics all contained in a fully electro-magnetic shielded housing.
- **Horizontal Drive Mechanics** - there are two versions of the horizontal drive systems:
  - Partial Drive (Basic Table) 154 cm scan range
  - Telescopic Drive (Whole Body option) 205 cm scan range
- Headphone transducer and Nurse Call sensor
- **Cable Guide** - a protective flexible chain assembly used to route cables to and from the Table Top.
- **Micro-switches and sensors** - for horizontal movement and trolley docking (not shown here).

Partial Drive

The basic table uses a Partial Drive assembly consisting of a single belt drive mechanism which is attached to both ends of the table top and driven by the MSDS.

Figure 92 *Partial Drive Assembly*

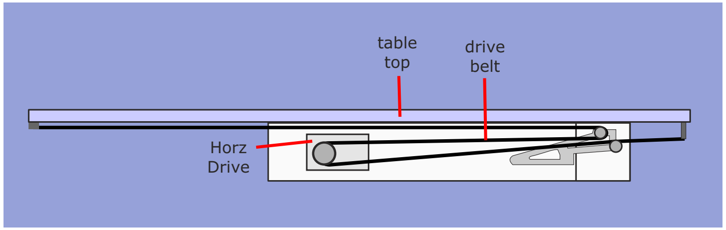
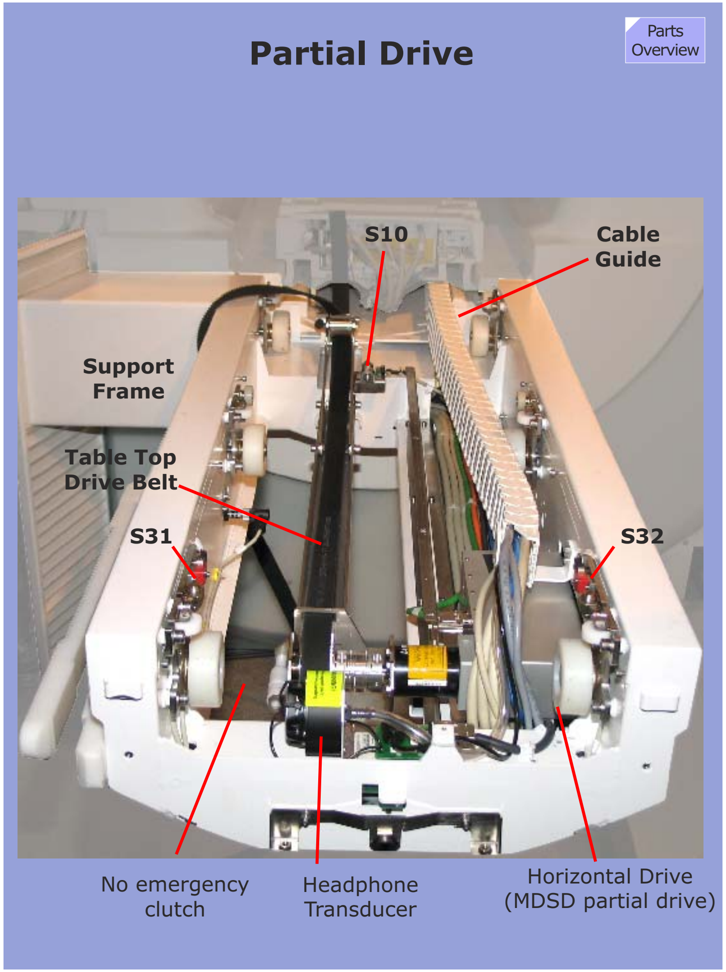


Figure 93 *Support Frame with Partial Drive*



Whole Body Drive

The Support Frame consists of the following components:

- Energy Chain - a cable-routing mechanism routing all cables to and from the Table Top.
- **MDSD** - a horizontal drive that consists of a AC-Synchronous motor with an integrated gear-box, position encoder and drive control electronics all contained in a fully electro-magnetic shielded housing.
- Alarm Squeeze Bulb Sensor - (not shown here)
- Acoustic transducer - (not shown here)
- **Telescopic Drive** - a new drive mechanism consisting of a cantilever drive sleigh and a telescope outrigger which provides an extended Table Top drive range of 205 cm. This telescope drive assembly is driven by the MSDS via a double-sided toothed belt driven by a double-sided toothed belt.
- **Sensors** - for horizontal movement and trolley docking (not shown here).

Figure 94 *Telescopic Drive Assembly*

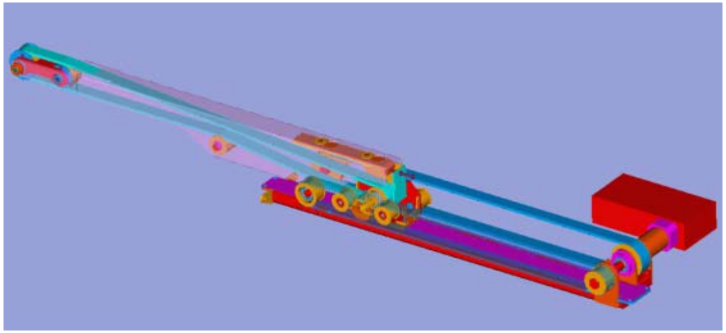


Figure 95 *Support Frame with Telescopic Drive*

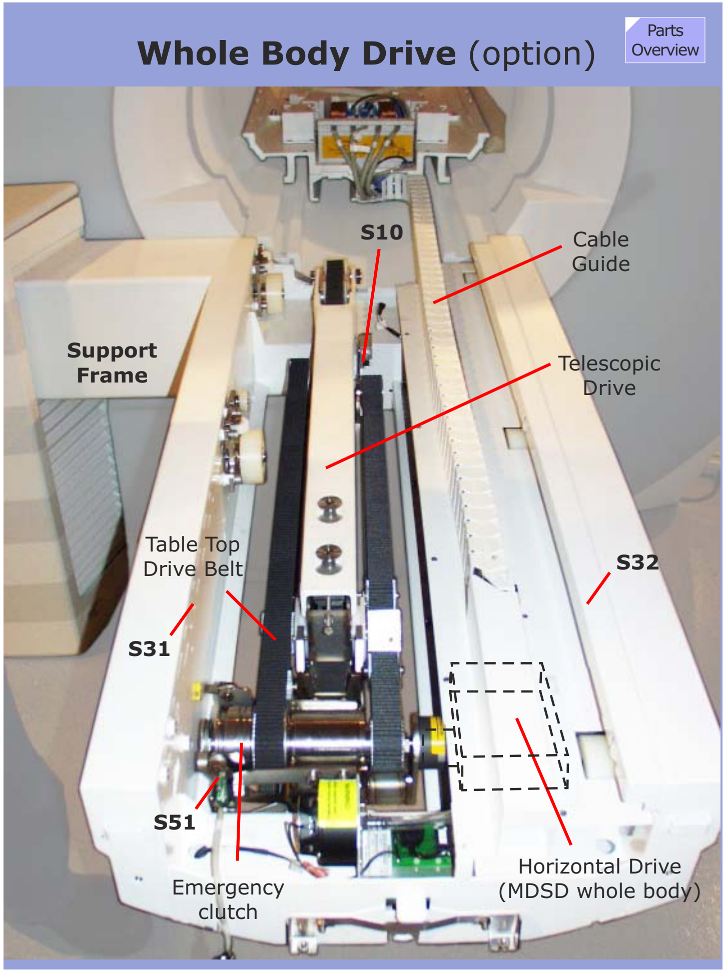


Table Top

General

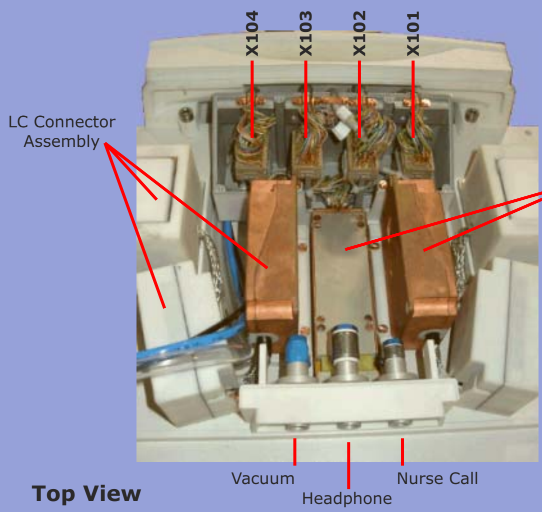
A standard Avanto system is equipped with a fixed Table Top. When fitted with the Trolley option, it will have a removable Patient Table Top which can be separated from a lower support plate via the Trolley.

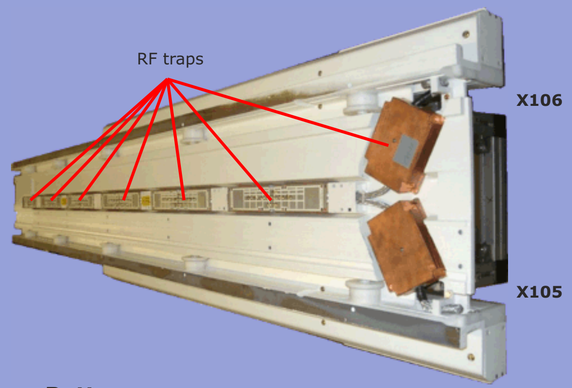
The Table Top contains:

- Coil connector RF-wave traps
- Connection for Vacuum Cushions (option)
- Connection for head phones
- Connection for Alarm Squeeze Bulb
- RF-connectors - they support the Tim applications (for details please refer to the RF-description)
- Integrated RF-wave traps

Figure 96 *Table Top Assembly*

Parts Overview
Coil Connectors





Control Electronics

General

The Control Electronics consists of the **Control Unit A4100** assembly located at the left-front side of the magnet, close to the Lifting column (see Patient table, Overview). It consists of:

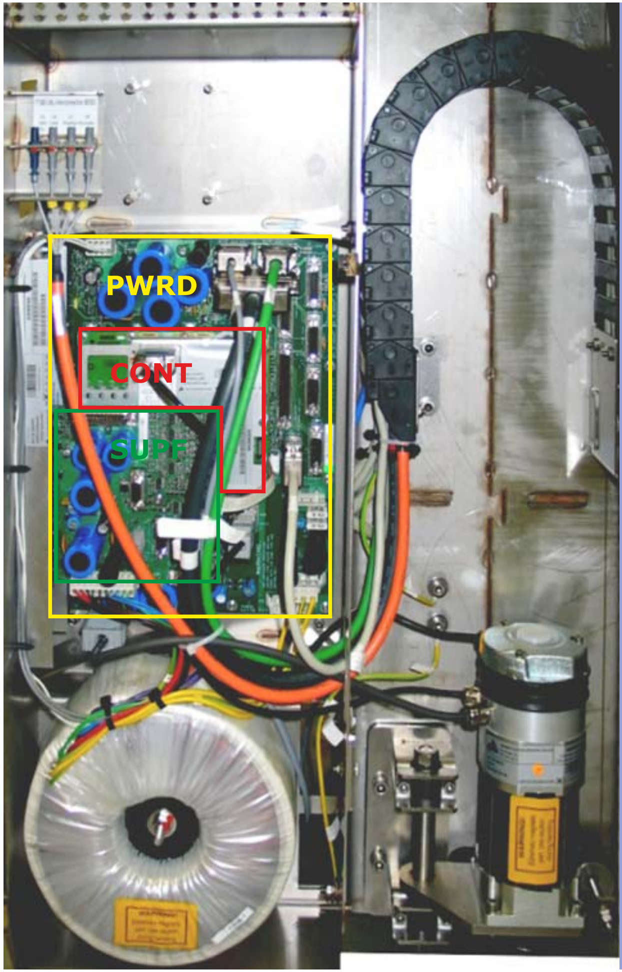
- **CONT A4140** is the communication interface to the CAN-bus.
- **Transformer A4114** and
  PWRD A4110 (Power Driver for Whole Body only, A4111 for Whole Body and Partial Drive) produce various operating voltages, generate vertical motor drive current, circuitry for the Emergency Stop function and connection interfaces to the peripheral components.
- The **SUPF A4120** (Supplied Functions) is a multi-purpose board for the supply of Patient-Fan, -Light, -Video camera as well as PDAU (see PMU-option) and Gradient Coil temperature-monitoring.

The remaining Patient Table electronics are:

- **Vertical Drive A4311.** Located at the Lifting column.
- **MDSD A4320.** Horizontal drive motor assembly located in the right side of the Support Frame.
- **Switch Terminal A4116** (A4115 for Trolley option). To connect switches and sensors to the Control Unit A4100. The Switch Terminal is located inside the Support Frame.
- **Peripheral Components** integrated into the magnet covers: Control Panels, Displays, Light Markers, Tunnel Light, Patient Fan, Microphones, acoustic transducer, and Air Temperature Measurement Unit.

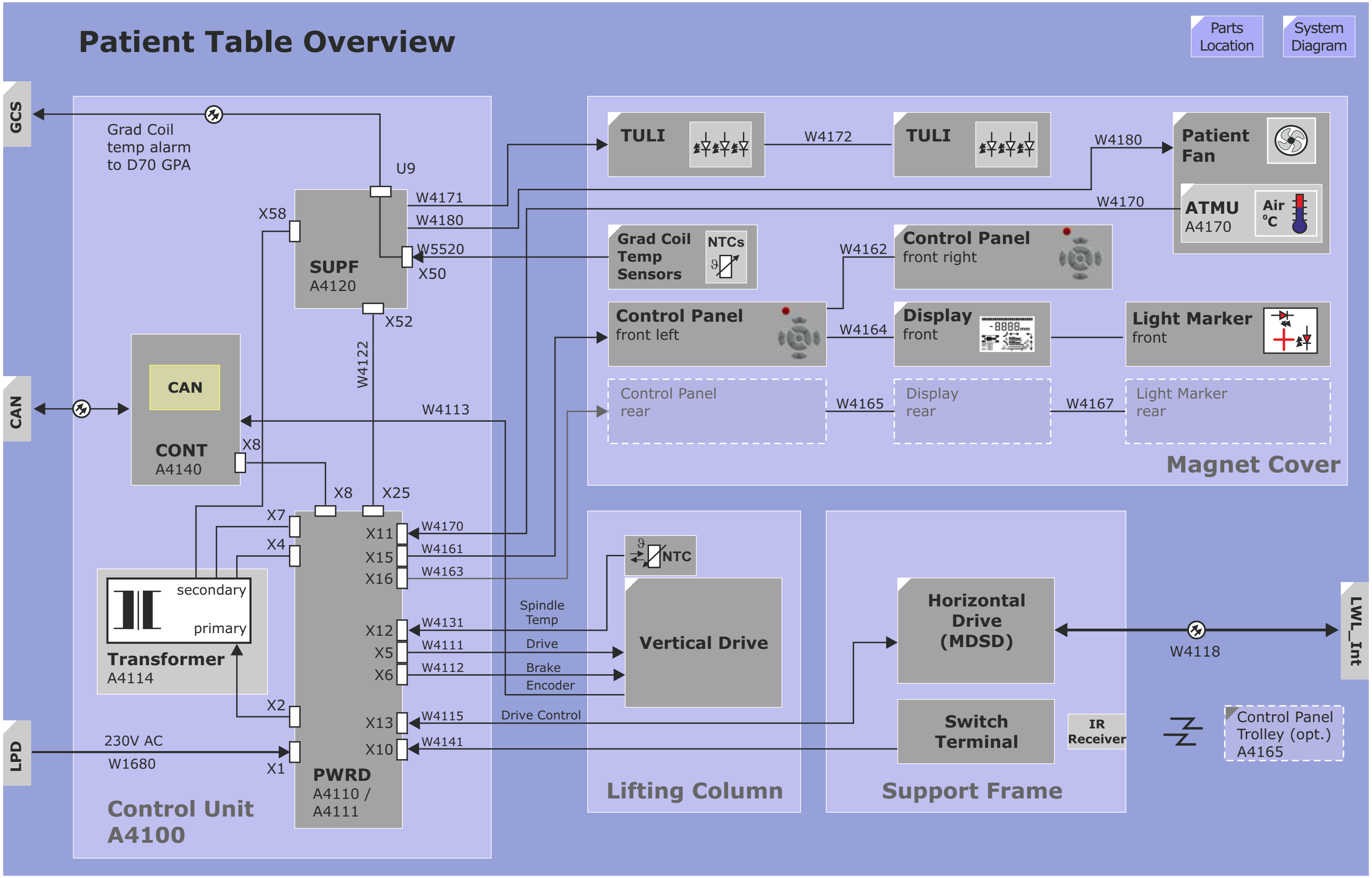
NOTE The Control Electronics has to be configured with switches S1.1 and S1.2 on the PWRD A4110 / A4111 (see S1 switch description on page 147).

Figure 97 *Control Unit Assembly*



Parts Overview

Figure 98 *Patient Table Overview Diagram*



Horizontal Control

Hardware Overview

The components involved in Horizontal control are:

- Control Panels
- CONT A4140
- PWRD A4110 / A4111
- MDSD (move during scan drive) A4320
- **Switch Terminal A4116**
  (A4115 in case of an installed Trolley option)
- Transformer A4114

Horizontal Drive Commands

Horizontal movement can be initiated either with the control panel keys or by the *syngo* MR software via CAN commands. On-board logic convert the key or CAN commands and send them over a serial communication line to the Horizontal drive MDSD.

When a measurement is started the CAN-Bus is put into an idle-mode to avoid RF-interference to the MR-signal.

Horizontal Power Stage, Position Detection

The drive commands from the CONT A4140 are routed via PWRD A4110 / A4111 to the MDSD A4320. Here, a regulation circuit monitors the actual horizontal Table Top position, detected by an encoder. If a deviation from the nominal position is detected (e.g. drive commands are applied, or somebody tries to move the Table Top by hand), a new motor current is calculated. It is fed via a pulse-width modulated driver- and power-stage to an AC-synchronous motor, that is part of the MDSD box.

The driver is supplied with 24 VDC by the PWRD (green LED H3, Fuse F17). The 60 VDC Power Stage supply voltage is switched on by a logic (green LED H25, Fuse F10) during horizontal travel.

To be able to detect the absolute horizontal position, the table has to be moved to home position after switching on power. That may be also necessary to clear specific errors. Switch S10 closes and detects the reference position, from where any offset is recognized by increments, counted by the position encoder. The voltage (24V_DC_SWT) for switch S10 is generated at the PWRD A4110 / A4111, a green LED (H2) lights up if the voltage is present. Fuse F16 protects against short circuit.

A double-sided tooth belt, driven by the MDSD-motor, moves a "cantilever" drive sleigh and via telescope outrigger the Table Top (see Support Frame description).

NOTE	The MSDS has an RF-shielded housing to avoid RF-interferences in the image. Opening this component may damage the seals and cause RF leakage!

Emergency Clutch

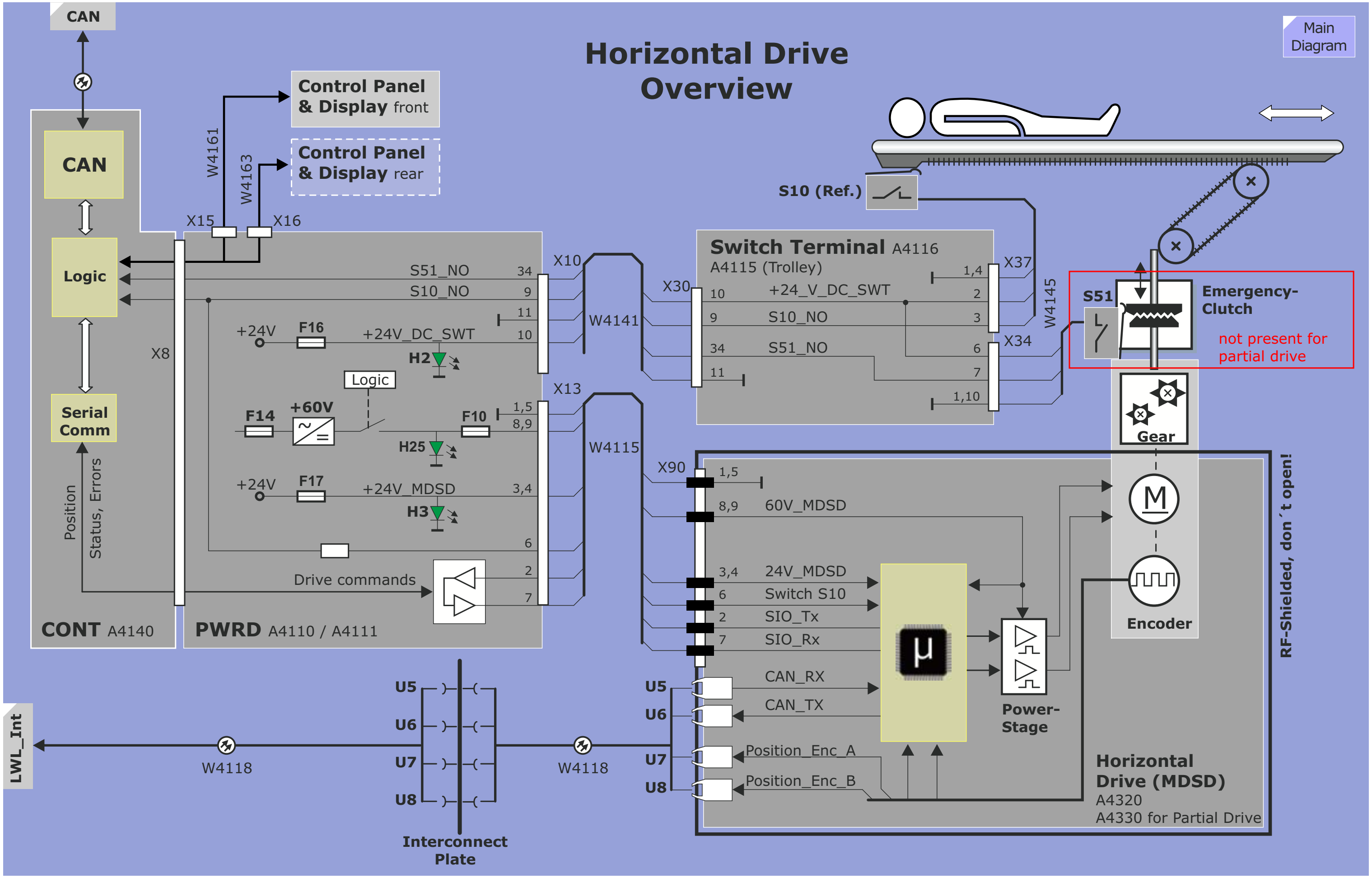
In case of emergency, the operator can release a mechanical clutch to decouple Table Top from the horizontal drive mechanics. Now, the Patient can be easily pulled out of the bore by hand. Switch S51 opens and reports the status to the CONT A4140. After resetting the clutch, the horizontal table position has to be re calibrated by driving the Table Top to home position again.

NOTE	If a system is equipped with the partial drive no Emergency Clutch and monitoring switch S51 is present.

Tim Whole Body Suite (option)

To support Whole Body examinations the system can be equipped with the "Tim Whole Body Suite" license that activates the full 205 cm scan range.

Figure 99 *Horizontal Control Overview Diagram*



Vertical Control

Hardware Overview

The components **involved** in vertical movement are:

- Control Panels
- CONT A4140
- PWRD A4110 / A4111
- **Vertical Drive A4311** (vertical motor assembly)
- **Switch Terminal A4116** (A4115 for Trolley option)
- Transformer A4114

Vertical Drive Commands

When vertical move buttons on the Control Panel are activated the respective command is sent to the CONT A4140 over the I2C bus. If the table is in a position to allow vertical movement (determined by various micro-switches) and no errors are present, speed regulation software generates a PWM drive signal which is sent to a power stage on the PWRD board for generating the motor current.

Patient Table status and errors are reported to the system over a CAN bus connection. When a measurement is started, the CAN-Bus is put into an idle-mode to avoid RF-related interferences.

NOTE	For service purposes, a hand crank is delivered to allow manual movement.

Vertical Power Stage, Speed Regulation

The pulse-width modulated nominal current values from the CONT board drive the Power Stage to create the motor drive current. A green LED (H26) indicates the 140 VDC drive voltage is present.

The Vertical Drive A4311 consists of an AC-synchronous motor with an integrated movement encoder and a brake assembly. The movement encoder signals are fed back to the CONT board via cable connection W4112 where they are used for detection and regulation of vertical movement speed.

Vertical Brake

The mechanical friction of the ball-bearing spindle is not sufficient to lock the vertical position safely. To avoid safety hazards, two independent vertical brakes are implemented:

- A **mechanical brake** at the bottom side of the spindle
- An **electromechanical brake**, part of Vertical drive A4311

The mechanical spindle brake engages during down-movement only. It has no friction in the opposite direction. When moving the table excessively up and down, the brake might overheat (won´t happen during normal operation). An attached sensor reports the actual brake temperature via cable connection W4131 to the PWRD A4110 / A4111 where it is digitized and reported to the CONT A4140 via the internal I2C-bus.

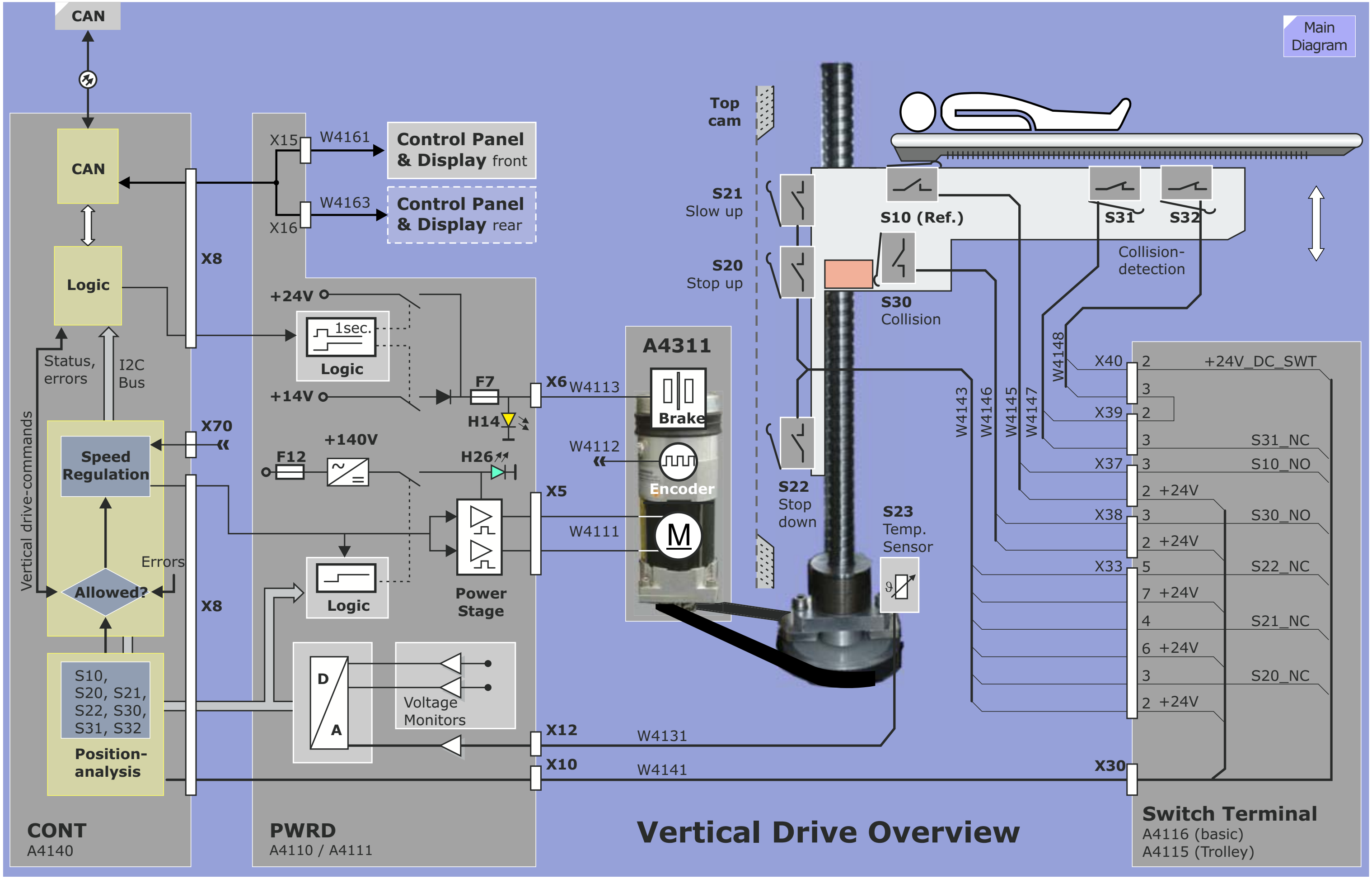
In case of overheating, a temperature warning is generated and sent to the system over the CAN Bus. If excessive travel continues, the CONT disables the "down" direction and reports a temperature alarm. In that case, the Patient table can still be moved up fully, during the following examination the brake will cool-down again.

The electro-mechanical brake locks if its power is removed. When the vertical motor is activated, a logic at the PWRD A4110 / A4111 switches on 24 VDC to release the brake. After one second, the logic removes the voltage and switches on 14 VDC to avoid brake over-heating. A yellow LED (H14) at the PWRD indicates the brake status. In case of electrical overload, fuse F7 trips.

Vertical Collision Detection

If vertical down movement is blocked by an obstacle, the Support Frame gets lifted from the spindle nut and switch S30 opens. If the blockage tilts the Table Top, switch S31 and S32 (connected in series) will open and block any further down-movement. An error message is generated, but still the table up-movement is possible. Now, the obstacle can be removed.

Figure 100 *Vertical Control Overview Diagram*



Control Panels and Displays

Hardware Overview

The following panel and display types are used:

	Avanto	Espree	Notes
Front-left Panel	A4161	A4561	
Front-right Panel	A4162	A4562	
Optional Rear Panel	A4162	A4563	
Displays	LCM119	--	Control panels for Espree have integrate displays
Light Marker	front rear - optional	front rear - optional	The optional rear light marker for Espree is different to Avanto

The Control Panel provides keys for Patient Table motion, tunnel lighting, air flow as well as speaker and headphone volume. All keys are illuminated by backlight LEDs (brightness adjustable, see Service Procedures).

To avoid interference to the MR-signal, the CONT I2C Bus, Control Panels and Displays are put into an idle-mode during measurement. The hardware can be reactivated by the WAKE_PAN signal that is sent to the CONT board if movement keys are pressed.

Figure 101 *Control Panels and Displays Avanto*

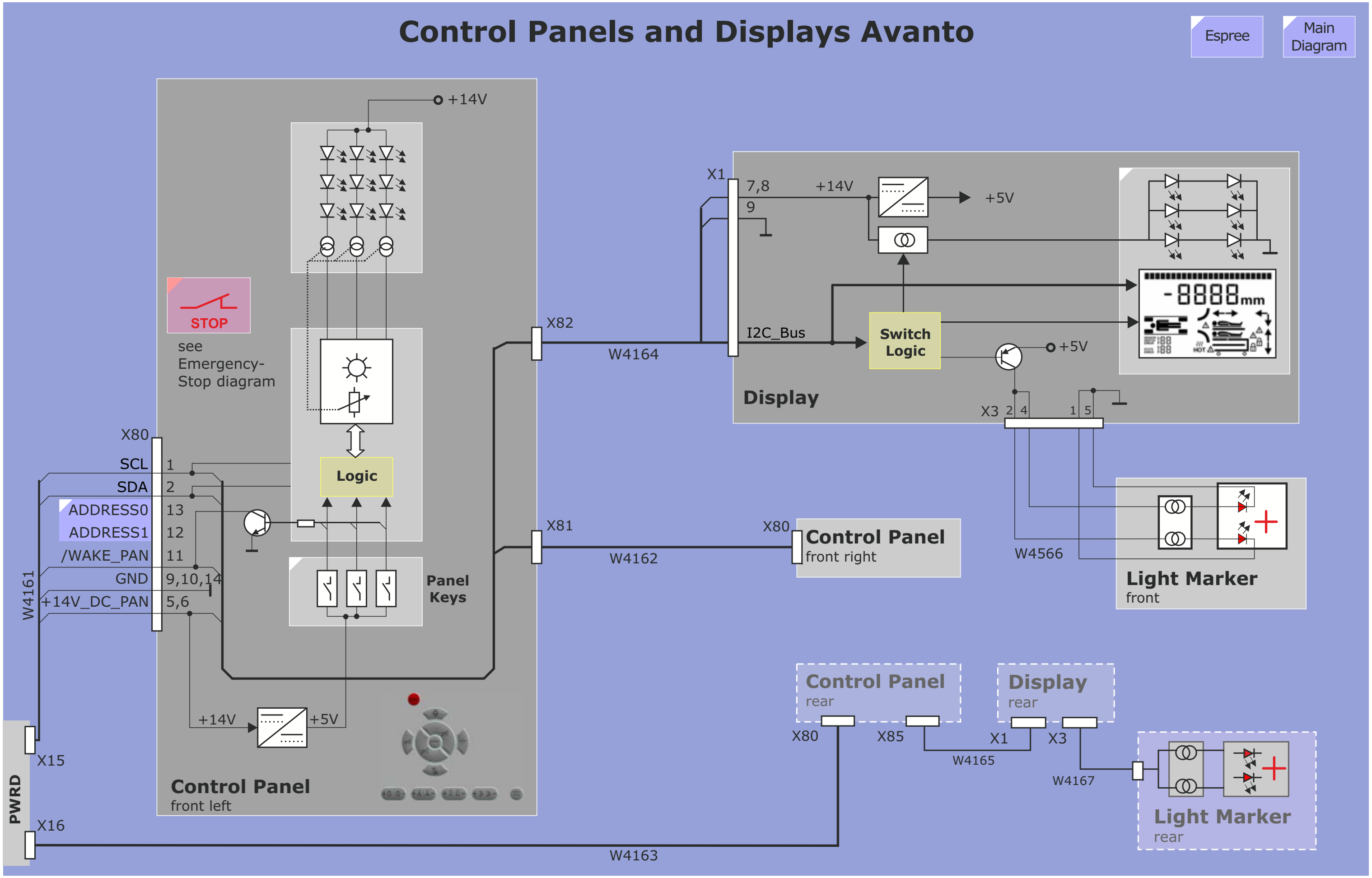
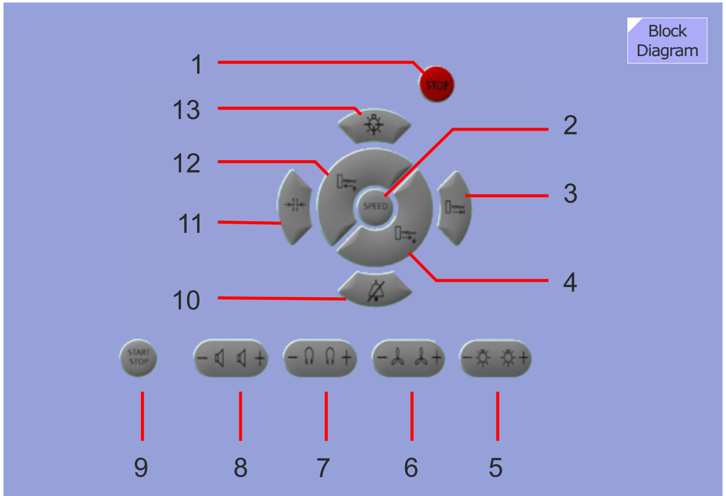
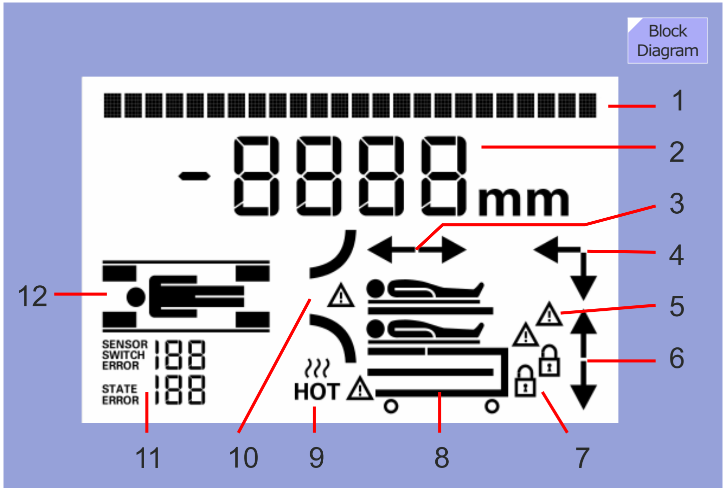


Figure 102 *Control Panel Keys*



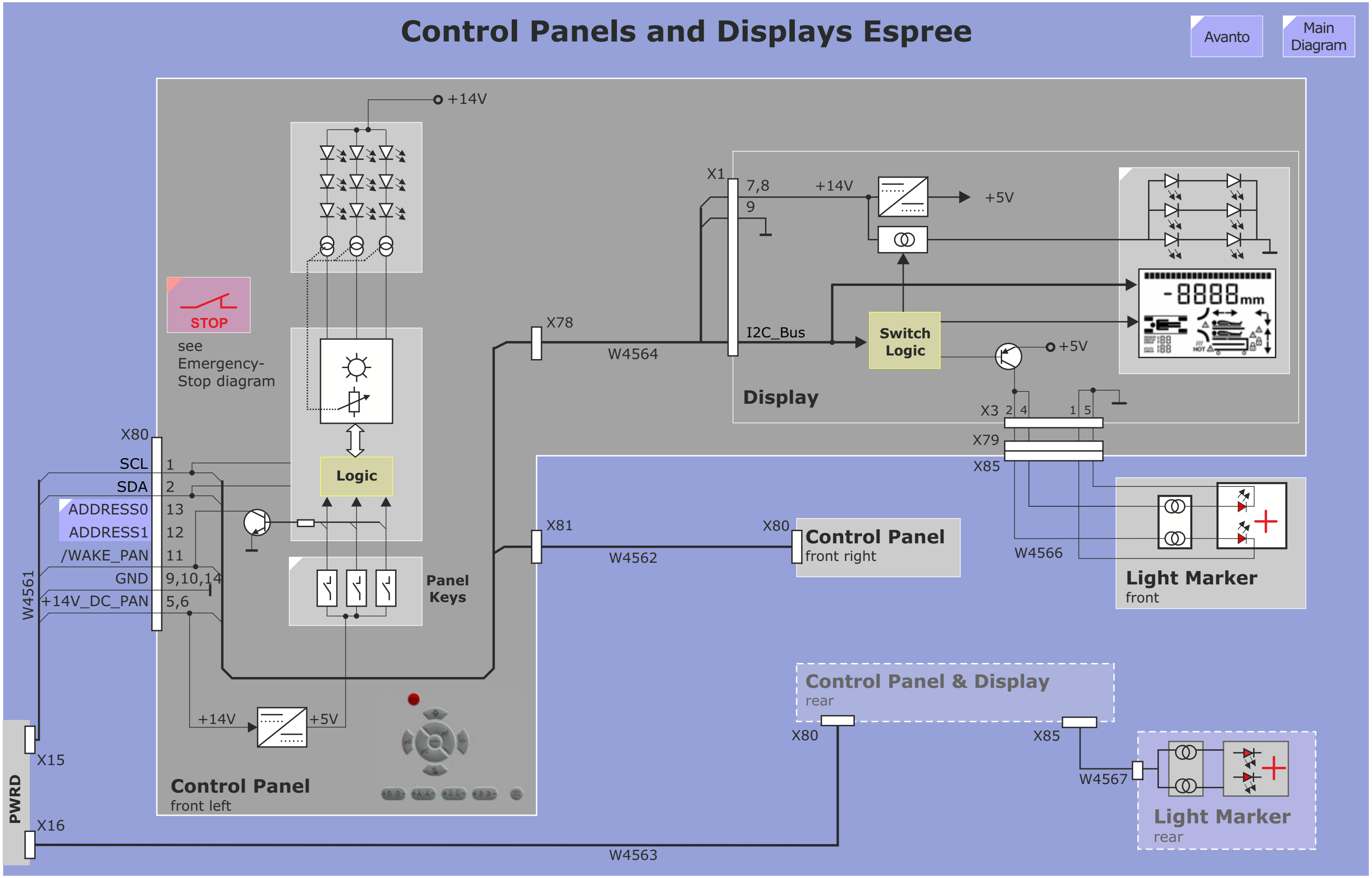
1) **Table Stop**: removes power from table drives
2) **Speed**: switches horiz. movement to high speed
3) **Home** : moves table fully out of the magnet
4) **Table Movement :** down/out
5) **Tunnel Lighting**: adjusts brightness
6) **Tunnel Ventilation**: adjusts airflow over patient
7) **Headphones:** music/speech volume
8) **Room Speaker**: music/speech volume
9) **Start/Stop** Measurement : also for service sequences
10) not used
11) **ISO Center Position**: moves table to magnet isocenter
12) **Table Movement:** up/in
13) **Laser Light Localizer:** on/off

Figure 103 *Display Graphics*



1) Test field for status and error messages
2) The actual horizontal table position
3) Direction arrows for table movement
4) Combined arrows (vertical, horizontal)
5) Collisions when moving the table in vertical direction
6) Direction arrows for table movement
7) Future use (Trolley)
8) Future use (Trolley)
9) Spindle brake overheating
10) Patient Table ok, flashes in case of severe errors
11) For service: status of switches, sensors and errors
The following pictograms can be displayed only if Host computer, MPCU and CAN-Bus are operational:
12) additional outputs in the text-field e.g. coil information
13) Coil socket assignments

Figure 104 *Control Panels and Displays Espree*

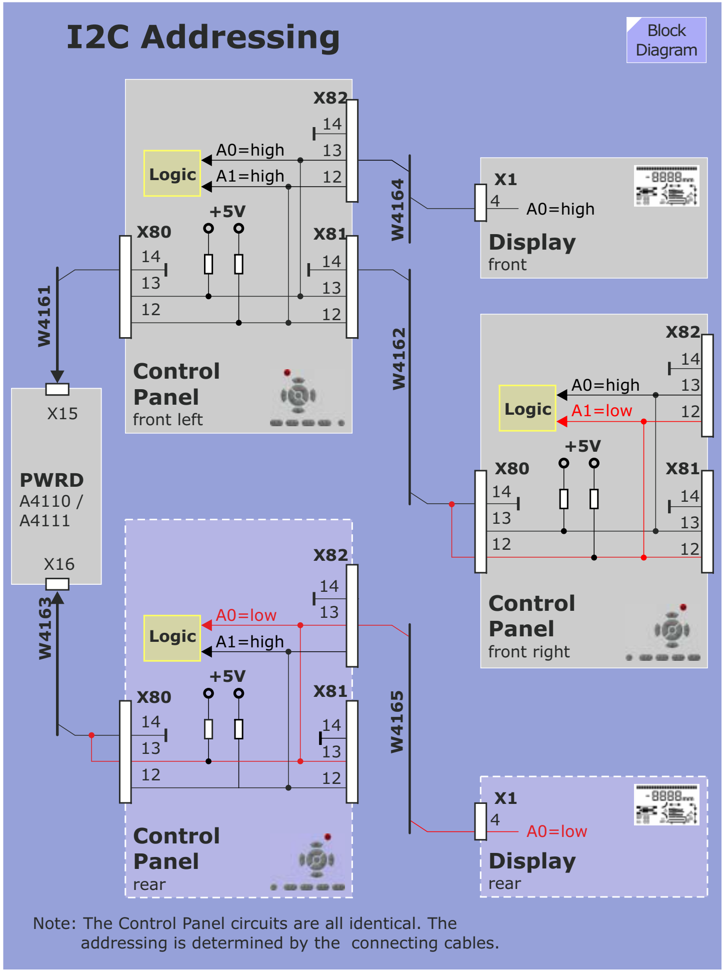


I2C-Bus Addressing

The Control Panels and Displays are connected via the external IIC-Bus and the PWRD A4110 / A4111 to the CONT A4140. They contain identical circuits and are not equipped with on-board addresses. The CONT can identify connected panels and displays during power-up by reading the address that is hard-wired by different cabling of the Address0,1 lines.

That facilitates troubleshooting quite a bit: panels and displays can be swapped or connected directly to the PWRD A4110 / A4111 as long as the correct address wire-out is maintained.

Figure 105 *I2C-Bus addressing*



Emergency Stop Circuit

Hardware Overview

The Avanto Patient table is equipped with up to four Stop buttons found at these locations:

- Two front Control Panels
- (Optional) back Control Panel
- Intercom Operating Unit

Stop Circuitry

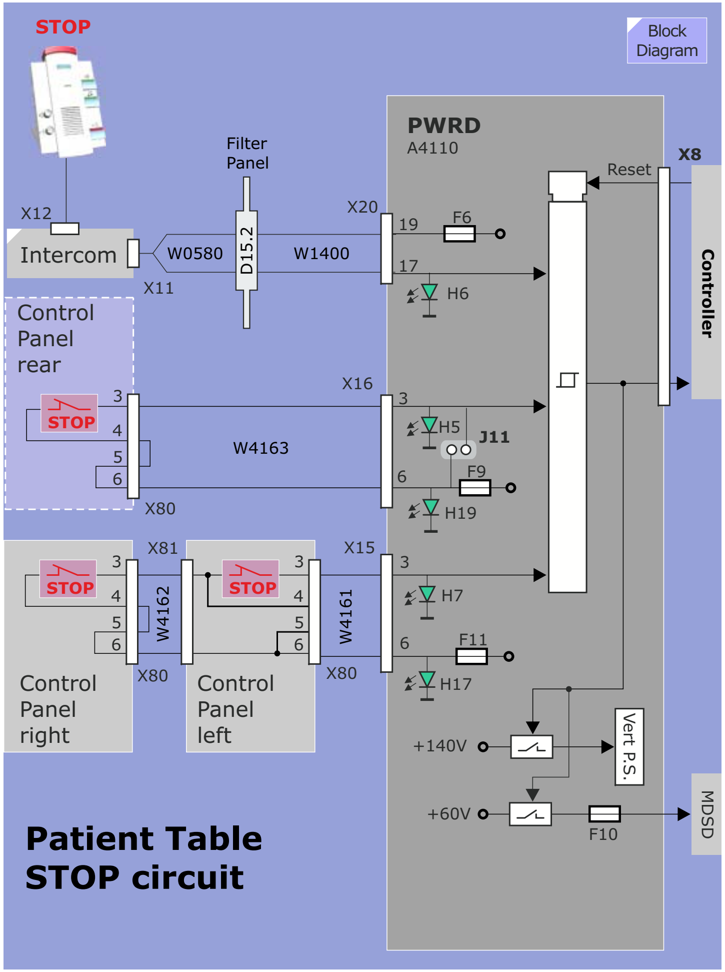
Each circuit uses the +14 VDC (+14V_DC_PAN) Panel operating voltage, generated at the PWRD A4110 / A4111 and fed there via fuses (F6, F9, F11). Two green LEDs (H17, H19) indicate the presence of the +14V_DC_PAN supply for the front and optional back Panel circuitry.

The voltage is routed back via the Stop buttons (closed contacts) to the PWRD A4110 / A4111, indicated by LEDs H5, H6 and H7 that light up. Pressing one of the buttons causes an interrupt, to be detected by an error flip-flop at the PWRD that disables the +140 VDC supply for the Vertical Power Stage and the +60 VDC for the MDSD Horizontal Drive. Additionally, the Stop-condition is reported via CONT A4140 and the CAN-Bus to *syngo* MR.

To reset the Table stop, the two table movement keys at one of the Control Panels have to be pressed in a sequence one time.

NOTE If a rear Control Panel is NOT connected, Jumper J11 on the PWRD A4110 / A4111 has to be inserted. If the rear Control Panel is installed, J11 must be removed or the Stop button will not work.

Figure 106 *Emergency Stop Circuit*



ATMU

Background

Prior to starting a measurement, the RF-Safety Watchdog (RFSWD) software calculates the SAR look ahead parameters. Since the maximum allowed RF exposition to the patient also depends on the ambient air temperature, it has to be measured. This is achieved by the Patient Environment Temperature sensors of the ATMU (Air Temperature Measurement Unit), that are located close to the air inlet of the Patient Fan housing.

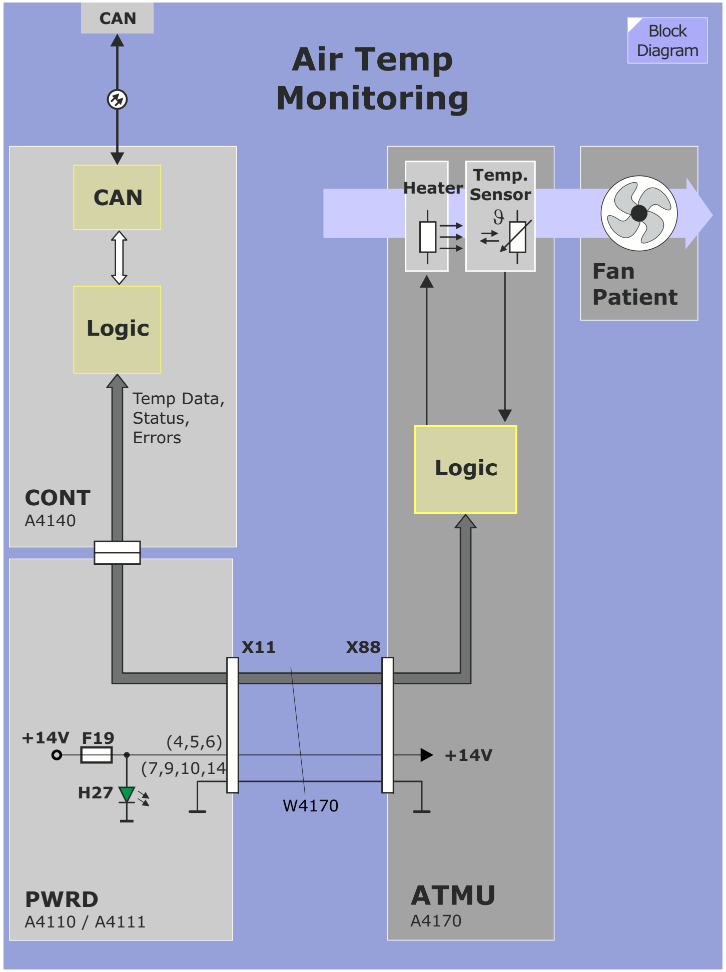
Air Temperature Monitoring

Via the AMC and CAN_Bus connection, a request is sent to the CONT A4140 to read the actual air temperature at the ATMU A4170. The request is sent via the external IIC-Bus connection to the ATMU, where a temperature measurement is started and the the actual temperature data is reported back to the RFSWD.

Temperature Sensor Check

The ATMU Temperature Sensor can be tested in the Service Software / QA / Expert Mode / Temp Sensor Check (see Service Routines).

Figure 107 *ATMU Block Diagram*



Gradient Coil Temperature Monitoring

Gradient Coil Temperature Measurement

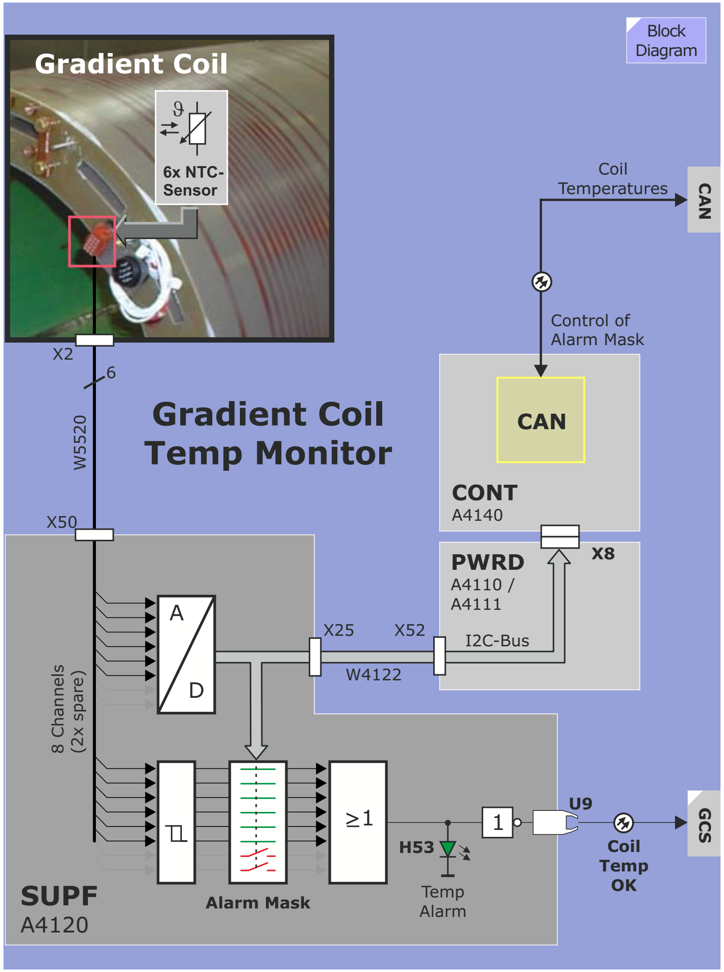
The temperatures of the Gradient Coil windings are monitored by the SUPF A4120 board. The gradient coil has six NTC resistors, one located on each of its six windings which are fed to a comparator logic on the SUPF A4120 for evaluation. If the gradient coil temperature exceeds the limits, the GPA will be switched off by removing the **Temperature OK** sum signal (FOC U9 SUPF to U1 D70 at the GPA. Light on = all temperatures are within limits).

Additionally, the temperature values are fed via the IIC-Bus connection to the CONT A4140 where they can be read on the CAN-Bus by the host computer.

Alarm Mask

The SUPF temperature detection logic is equipped with eight monitoring channels, of which only six (6 NTCs) are currently used. The two unused channels are masked out by an Alarm Mask logic, loaded by the host computer via CAN-Bus and internal IIC-Bus of CONT A4140.

Figure 108 *GC Temperature Monitoring*



Patient Fan, Light and Auxiliary Supply

Patient Fan

For increased patient comfort a variable-speed cooling fan, having three fan speeds, can be adjusted at the Control Panels or via syngo MR. The commands are routed from CONT A4140 to PWRD A4110 / A4111 and SUPF A4120 via the internal I2C-Bus connection. A D/A converter at the SUPF feeds out the control voltage (0-10 V, indicated by LED H60) for the fans speed control circuit. The fan operating voltage is supplied by Transformer A4114 (36 VAC), rectified on board and indicated by LED H58 (FAN_DC_PAT, 48 VDC).

Tunnel Light (TULI)

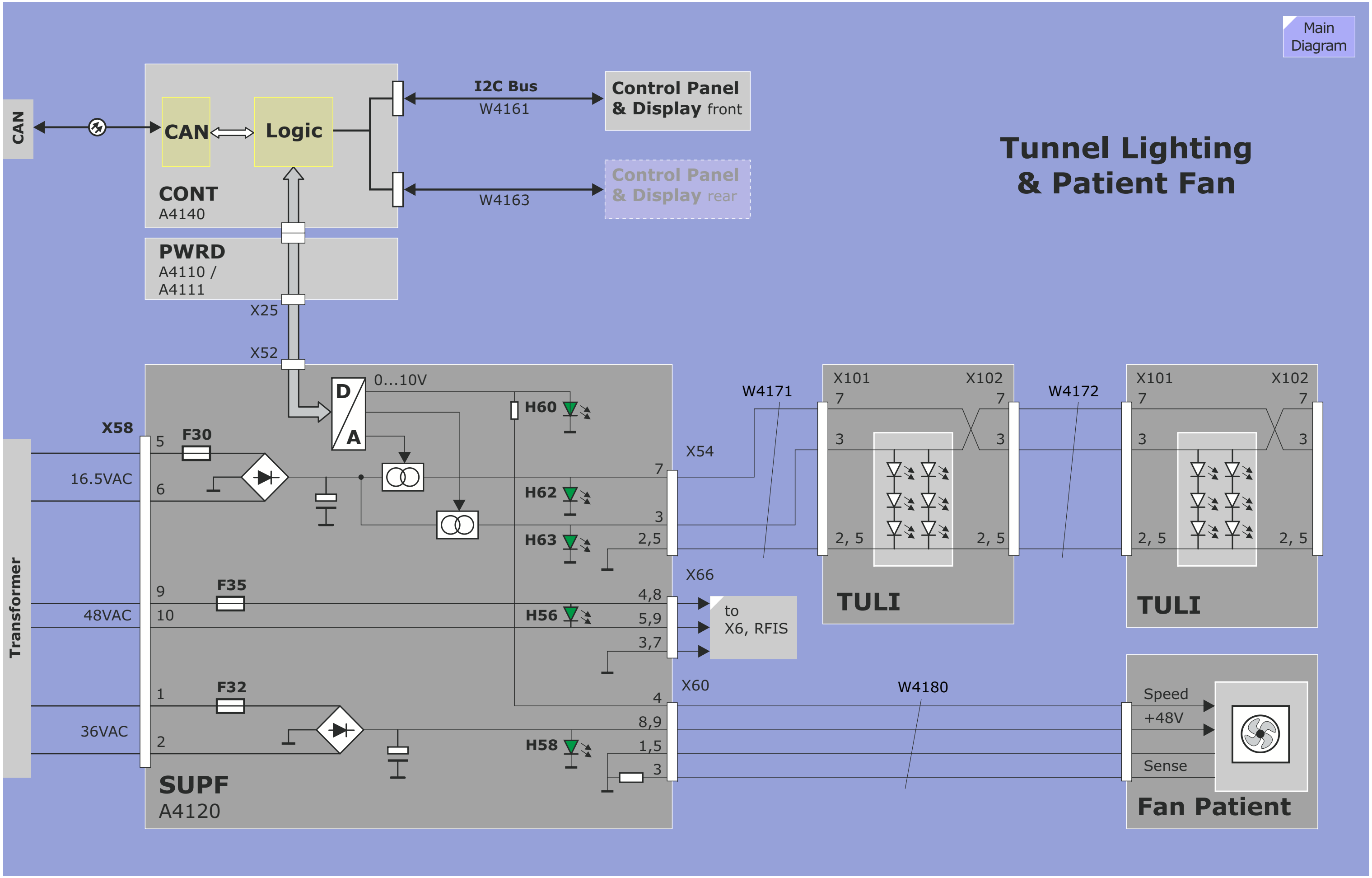
Similar to the Patient Fan, the brightness of the two back LED-Tunnel Lights is adjustable in three steps.

The D/A converter at the SUPF sets up two independent brightness current-control circuits, supplied by a rectified 16.5 VAC voltage. LED H62 (for TULI 2) and H63 (for TULI 1) indicate the presence of each supply.

Auxiliary Supply

An auxiliary supply voltage (48 VAC) is taken from Transformer A4114 and fed to connector X6 of the RFIS for generation of the 500 VDC Body Coil static-detuning voltage. If the voltage is present, LED H56 lights up.

Figure 109 *Patient Fan, Tunnel Light and Auxiliary Supply*



Switches

Switch	Location	Description
S20	Lifting Column	S20_NC, Vertical upper end position. Opens when position is reached, enables horizontal movement.
S21		S21_NC, Vertical slow speed. Opens approximately 40 mm before upper end stop (S20) is reached, remains open until upper mechanical end stop is reached.
S22		S22_NC, Vertical lower end position. Opens approx. 40 mm before lower mechanical end stop is reached. Table starts breaking when activated and passes the switch by about 35 mm.
S23		TMP_Y, Spindle brake temperature sensor
S30		S30_NO, Vertical collision detection, switch at spindle nut opens if support frame is lifted from spindle nut by force.
S10	Support Frame	S10_NO, Horiz. home position. Reference switch, closed if table is fully outside the magnet, enables vertical movement.
S31, S32 (connected in series)		S31_NC, Table Top vertical collision detection. Switch opens when the Table Top is lifted by force.
S51		S51_NO, emergency clutch release (decouple). Switch opens and horiz. reference point gets lost
S1.1 (lower)	PWRD A4110 / A4111	Position on=Removable Tabletop (Trolley) Position off=Standard Table Top
S1.2 (upper)		Position on (left)=not used Position off (right)=not used, default pos.

LEDs

LED	Location	Description
H1 green	PWRD A4110/ A4111	+24V_DC_ORT, auxiliary voltage for Operational Table (option)
H2 green		+24V_DC_SWT, Switch and sensor power supply (unswitched)
H3 green		+24V_DC_MDSD, Power supply 24V MDSD
H4 green		/WAKE_TMP_COIL, off during wake signal by temperature monitor coils (not used)
H5 green		/STOP_PAN_R, off with open stop circuit of rear operating panel, J11
H6 green		/STOP_ICON, off with open stop circuit of intercom
H7 green		/STOP_PAN_F, off with open stop circuit of front operating panel
H8 green		/STOP_ORT, off with open stop circuit of Operational Table (option), J12
H9 green		/STOP_SWT, off with open stop circuit of SWT (not used)
H10 green		/WAKE_PAN_F, off with wake signal from front operating panel
H11 green		+15V_PWRD, internal power supply +15V
H12 green		/WAKE_PAN_R, off with wake signal from rear operating panel
H13 green		+5V_PWRD, internal power supply +5V
H14 yellow		BRAKE, lights when vertical brake at A4311 is unlocked
H15 green		/WAKE_SWT, off with wake signal by SWT (not used)
H16 green		+DC_CONT, Supply voltage CONT A4140 (10V)
H17 green		+14V_DC_PAN_F, Power supply front control panel
H18 green		+14V_DC_SWT, Power supply SWT component group (A4115)

LED	Location	Description
H19 green	PWRD A4110/ A4111	+14V_DC_PAN_R, Power supply rear control panel
H21 green		-5V_PWRD, internal power supply -5V
H22 green		+140V_DC_PSY, Power supply network vertical output stage (PWRD)
H23 green		+15V_H_PWRD, internal power supply +15V
H24 green		60V_DC_MDSD, Power supply network horizontal output stage (MDSD)
H25 green		60V_DC_MDSD_ZK, (switched) Intermediate voltage horizontal output stage (MDSD)
H26 green		PSY_DC_BUS, (switched) Intermediate voltage vertical output stage (PWRD)
H27 green		+14V_DC_ATMU, Power supply ATMU
H30 green	SWT A4115	+14V_SWT, Power supply SWT component group (A4115)
H31 green		+5V_SWT, SWT internal power supply 5V (Trolley option)
H32 green	SWT A4115, A4116	+24V_DC_SWT, Supply voltage for switches and sensor S40 (Trolley option)
H33 yellow	SWT A4115	OUT_DC_SWITCHES, Switched supply voltage for sensor S33 (Trolley option)
H34 yellow		IR_DATA, Flashes during data reception from the IR remote control unit (Trolley)
H50 green	SUPF A4120	+5V, SUPF internal power supply +5V
H51 green		+15V_SUPF, internal power supply +15V
H52 green		-15V_SUPF, internal power supply -15V
H53 red		ERR_TEMP_GRAD, Temperature rise on gradient coil
H54 red		ERR_TEMP_BC, (not used)
H55 green		13.8V_AC(PDAU Supply), PDAU supply
H56 green		48V_AC(BC detune power supply), BC detune power supply
H58 green		FAN_DC_PAT, Equipment fan power supply (approx. 48V)
H59 green		+24V_PDAU, PDAU power supply
H60 green		FAN_CONT_PAT, Patient fan control voltage (0-10V)
H62 green		+DC_LIGHT2, Voltage for Light 2 (TULI)
H63 green		+DC_LIGHT1, Voltage for Light 1 (TULI)
H64 green		+13,5V_DC_VID, Video camera power supply (+13.5V)
H70 green	CONT A4140	+5V_ENC_Y, (switched) Supply voltage for lifting axis encoder
H71 green		+5V_CONT, Supply voltage for CONT
H72 yellow		FW running, Flashes when firmware (boot loader) is running
H73 green		LW running, Flashes when loadware is running
H74 red		ERROR1, Error display, error number, see display and host notification
H75 red		ERROR2, Not used (reserved for additional error display)
H80 green	PAN A416x	+14V_DC_PAN, Supply voltage (not visible from outside)
H81 green		+5V_PAN, Panel internal power supply (not visible from outside)
H90 green	MDSD A4320	MDSD_24V, Supply voltage
H91 green		MDSD_60V, (switched) Intermediate circuit power voltage for vertical output stage

Fuses

Fuse	Location	Description
F1 10AF	PWRD A4110/ A4111	input voltage 230VAC
F3 0.2A		NCR_KEY1, Nurse call key 1
F4 0.2A		NCR_KEY2, Nurse call key 2
F5 0.2A		OUT_DC_SWITCHES, Switched power supply for switches; see also F8
F6 0.2A		INTERCOM, Power supply STOP circuit
F7 1.1A		BRAKE, Brake Y-axis (see LED H14)
F8 2.5A		18.6V_AC, raw voltage for+24V_DC-BRAKE (via F18, see LEDs H1, H2, H3, H11, H13, H21, H23)
F9 1.35A		+14V_DC_PAN_R, Power supply rear control panel (see LED H19)
F10, 4AT		+60V_DC_MDSD, Power supply MDSD intermediate circuit (see LED H25)
F11 2.5A		+14V_DC_PAN_F, Power supply front control panel (see LED H17)
F12 10AF		110V_AC, Raw voltage for output stage PWRD (see LED H22)
F13 0.2A		+14V_DC_SWT, Power supply SWT A4115 (see LED H18)
F14, 8AT		55V_AC, Raw voltage for output stage MDSD (see LED H24)
F15 0.5A		+24V_DC_ORT, Voltage for Operational Table, supplied via F8 (see LED H1)
F16, 0.5A		+24V_DC_SWT, Power supply 24V SWT A4115 (see LED H2)
F17, 0.5A		+24V_DC_MDSD, Power supply 24V MDSD (see LED H3)
F18, 9A		11.2V_AC, raw voltage for: +14V_DC_SWT, +14V_DC_PAN_F, +14V_DC_PAN_R, +DC_CONT, BRAKE (see LED H16, H17, H18, H19)
F19 0.2A		+14V_DC_ATMU, Power supply ATMU (see LED H27)

Fuse	Location	Description
F30 4A	SUPF A4120	16.5V_AC, raw voltage for: +5V internal SUPF Power Supply for Patient Light, Video Camera Supply (see LEDs H50, H64)
F31 1.6A		20.6V_AC, raw voltage for: +15V_SUPF, 15V_SUPF, +24V_DC_PDAU (see LEDs H51, H52, H59)
F32 5AT		36V_AC, raw voltage for patient fan power supply (see LED H58)
F35 0.3AT		48V_AC, raw voltage for BC detune supply (see LED H56)
F36 4A		13.8V_AC, PDAU power supply (see LED H55)

NOTE Most fuses are self-resetting (PTC-fuses), wait for cool down after error is cleared.

Jumpers

Jumper	Location	Default-Position	Description
J1	CONT A4140	Jumper fitted	Automatic loading of CONT A4140 loadware after power up. LED H73 blinks when loadware is running (except in sleep-mode)
J11	PWRD A4110/ A4111, close to X16	- - - - -	Must be fitted if the Control Panel rear A4162 option is not installed. Closes Table Stop circuit. If installed, the Jumper must be removed otherwise rear Stop button won´t work!
J12	PWRD A4110/ A4111, close to X14	Jumper fitted	Must be fitted if the Operational Table option is not installed. Closes Table Stop circuit.

Service Routines

Service test functions are built into the CONT A4140 and therefore not found under the SeSo Test Tools (except a communication and status test and a Temperature Sensor check in QA / Normal Mode).

Display of Current Errors

The table control is able to report errors in the following ways:

- **Via CAN-bus to the Host**
- **Numerically on the Patient Table display:** ("Error: nnn")
  In case of multiple errors, they will be displayed sequentially. The displayed number corresponds to the error message ID in the eventlog and TSG.
- **Error text on the Patient Table display:**
  If there has been no CAN-host communication since the last power-up, the error text is displayed in the text lines.

Reset of Table Movement Errors

To reset table movement errors (e.g. "Table Stop" button was pressed or Vertical Collision occurred), the "Table Movement Up/ In" and the "Table Movement Down/Out" buttons have to be pressed one time in sequence

Service Mode

The Service Mode is started by pressing a special key combination at one of the Control Panels. In "Service Mode" you can test:

- Switches and sensors
- Operating panels (including backlight brightness adjustment)
- Displays (including contrast adjustment)
- Temperatures (Spindle brake, PWRD and SUPF)

Debug Display

The "Debug display" allows internal software "states" to be reported during normal operation of the table. In case of severe problems, these states can help the HSC or Lab in solving the problem. When the "Debug display" is activated, you will find the following information at the left bottom corner:

- Display of the state number
- Display of switch status

Temperature Sensor Check

The ATMU Temperature Sensor can be tested in the Service Software / QA / Normal Mode.

When the test is started, the CONT A4140 switches off the Patient Fan and sends a test request to the ATMU where a heater resistor, mounted close to the sensor, is energized. The Controller software checks twice in a time frame of 30 seconds to see if a temperature increase of 5 degrees centigrade has occurred. The test will fail if no temperature increase is detected or if the sensor temperature prior to starting the test exceeds 35 degrees centigrade. Finally, the Patient Fan is switched on again.

NOTE	Before repeating the test, wait 15 minutes to allow the sensor to cool down.

Trolley (option)

Overview

To facilitate patient setup, the MAGNETOM Avanto / Espree can be equipped with a Removable TableTop (RTT) to be separated from the support plate with the help of a movable trolley. The essential differences with respect to the standard patient table are:

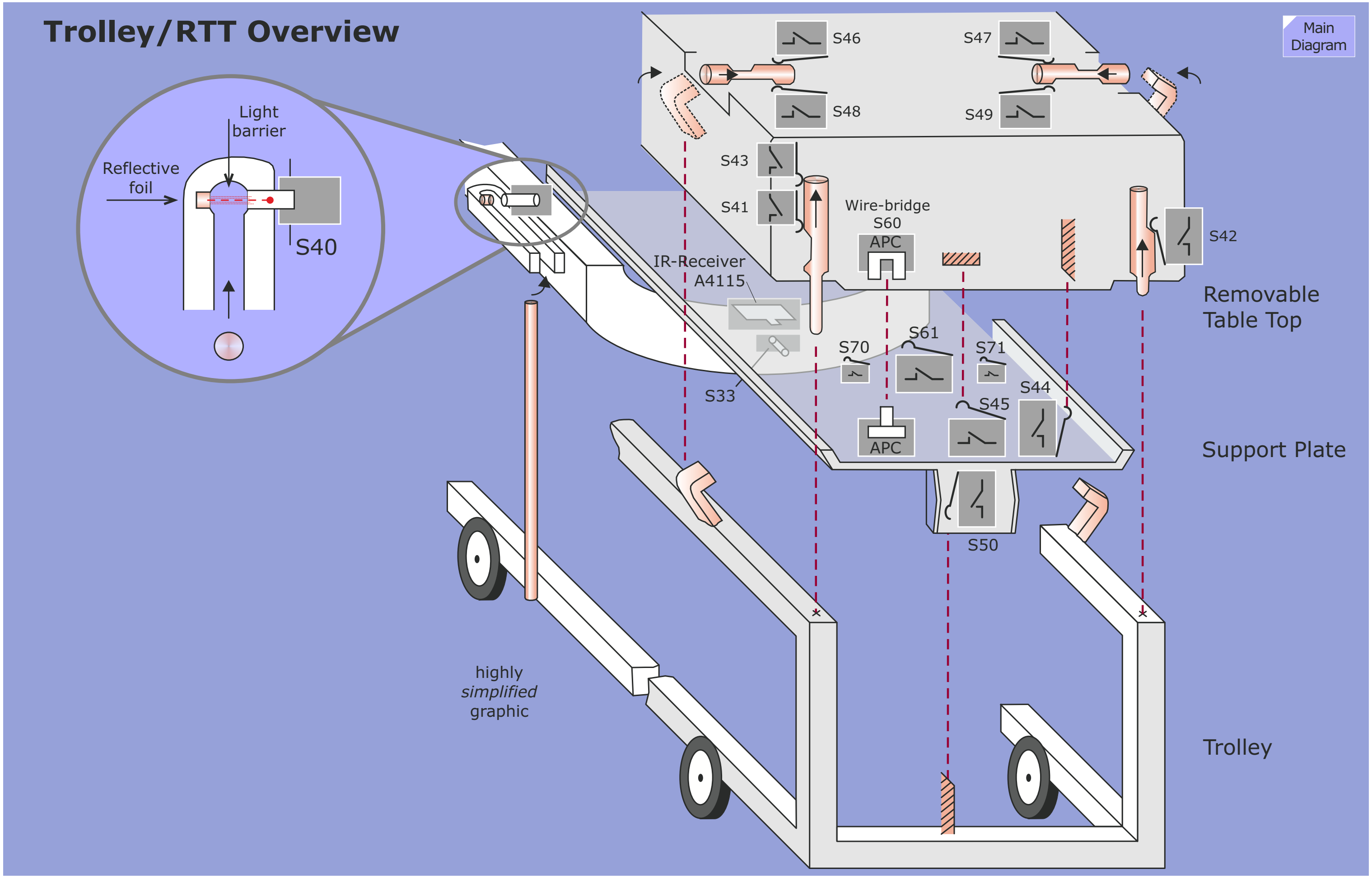
- Removable TableTop (RTT)
  Can be separated from the support plate with the trolley.
- Trolley
  Movable TableTop transport device, equipped with an IR remote control to drive the patient table in the vertical direction.
- Automatic Plug Connection (APC)
  Special plug in between RTT and support plate to connect the RTT switches to the table electronics. Opens automatically, if the RTT is separated from the support plate.
- Switch terminal RTT A4115
  Distribution board for support plate/RTT control switches. Contains an IR receiver for the trolley remote control.

NOTE	The trolley/RTT option must be enabled by a configuration switch S1.1 at PWRD A4110 / A4111.

NOTE	The Trolley/RTT hardware of the Avanto and Espree systems are different, although they look identical. Do not change Trolley parts between these systems.

NOTE	Upgrades of a standard system with the trolley/RTT option has to be performed by specially trained personnel (e.g. Hegele).

Figure 110 *Trolley Switch Overview*



Trolley/RTT Transfer Process

The Trolley/RTT operation is monitored and controlled by a set of additional switches and sensors located on the RTT, the Support Plate and the Support Frame.

Transfer of RTT from Support Plate to Trolley

- Table down movement, high speed
  When S41 is released, vertical travel is switched to "slow speed".
- Table slow-down
  As soon as S42 is actuated or S43 is released, the down movement is stopped. A minor residual movement is possible, however, the Automatic Plug Connection (APC) must not open at this point in time.
- Engaging RTT locking mechanism (foot pedal)
  Operation of the foot pedal will mechanically lock the RTT to the trolley. Both the trolley hooks must capture the RTT safely, monitored by S46 - S49. All RF coil plugs and air hose connectors need to be disconnected by the operator before further down movement is possible (see description in the following pages).
- Table down movement
  The table can be lowered down further, S45 detects the separation of RTT from the support plate and the APC will open. When reaching the lower vertical end position (valid for trolley operation only), S50 is actuated and the down movement stops. A minor residual movement is possible.
- RTT can be transported on trolley

NOTE RTT transfer to the trolley requires both Trolley hooks to be fully engaged/locked.

Transfer of RTT from Trolley to Support Plate

- Table up movement, high speed
  When S44 is actuated, vertical travel is switched to "slow speed".
- Table moving up slowly
  As soon as S45 is actuated, the up movement is stopped. A minor residual movement is possible, the APC must be fully connected at this point in time.
- Releasing the RTT locking mechanism (foot pedal)
  Both trolley hooks must be fully released and monitored by S46 - S49. Further up movement will be enabled.
- Table up movement
  When the RTT is elevated off the trolley frame, S42 is released and S43 is actuated. Vertical travel to the upper end position is possible.

NOTE RTT transfer back to the support plate requires that both trolley hooks are fully released/unlocked.

Optical Sensors

Two optical sensors are responsible for a safe, collision-free RTT transfer process.

- Trolley docking sensor S40 (docking bracket)
  Correct docking of the trolley is monitored continuously via light barrier S40. When correctly docked, the stainless steel trolley guide bar interrupts the optical connection between light barrier S40 and the reflective foil, mounted at the opposite inner side of the docking bracket (docked=high sensor output level). The +24V OUT_DC_SWITCHED voltage is switched off. The collision detection sensor S33 is no longer operational. When the trolley is removed or docked incorrectly, the light of sensor S40 is fully mirrored back by the reflective foil, the sensor output changes to low status and the collision detection sensor S33 is switched on (OUT_DC_SWITCHED voltage=+24VDC)

- Collision detection sensor S33 (table foot end)
  Any object blocking the detection range of optical sensor S33 will be recognized by the table electronics; the vertical movement will be blocked (blockage=low output level).

NOTE	The collision detection sensor S33 is switched off when the trolley is docked correctly (detected by S40).

Removal of Coil Plugs

To avoid mechanical damage, the operator must remove all connected coil plugs prior to the RTT transfer from the support plate to the trolley.

Currently (as of 03/05) the table electronics are not able to identify remaining plugs except for the two "horizontal" sockets X7 and X9 at the foot end of the table. Switches S70 and S71 will detect if the coil plug cover is open.

To avoid damage to the plugs, decoupling of the RTT from the support plate is blocked and a reminder message appears on the table display. After you acknowledge this with the "Speed" button (Control Panel), the RTT can be decoupled.

In future software versions, a coil-code check will be implemented, making sure that none of the coil plugs has been forgotten.

Removal of Air Hose Connectors

The following air hose connectors must be removed prior to RTT

transfer from the support plate to the trolley.

• Connector for vacuum cushions

• Connector for headphones

• Connector for alarm squeeze bulb

Plugged-in connectors are detected by switch S61 at the support plate (connector plugged in = low signal). RTT decoupling will be blocked.

IR Remote Control

The trolley is equipped with an infrared remote control to drive the patient table in the vertical direction. The IR sensor is located at the foot end of the table at the switch terminal RTT board A4115.

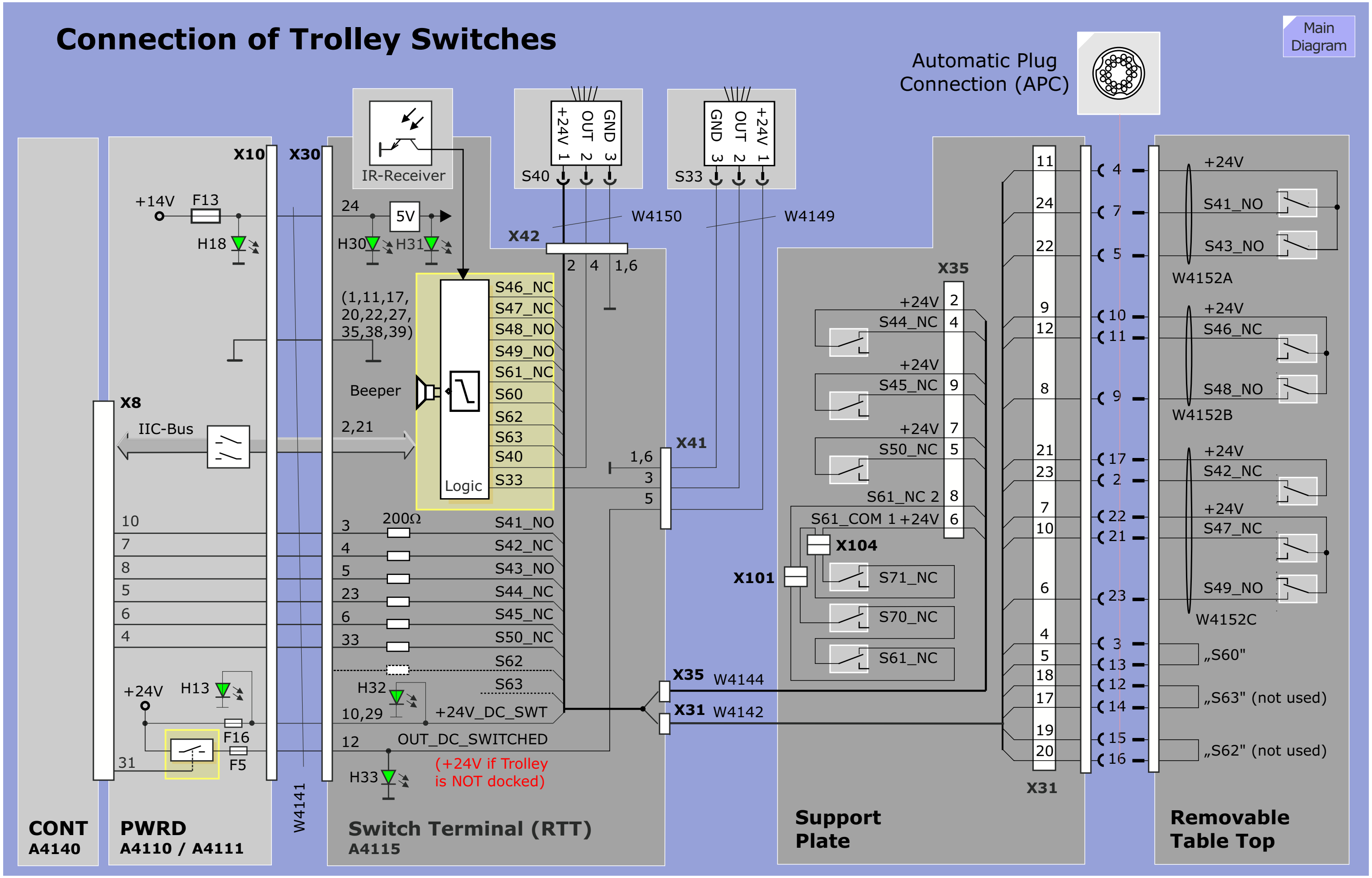
Switches

Plausibility Check of Switch Conditions

The plausibility of the logic status of numerous trolley/RTT switches and sensors is checked by the table electronics. In case of deviations from the predefined status, a table stop is generated and the respective error message is sent to the host.

Some specific switch errors cannot be detected by the plausibility check. They can be recognized by typical table malfunctions (see TSG).

Figure 111 *Trolley Switch Connections*

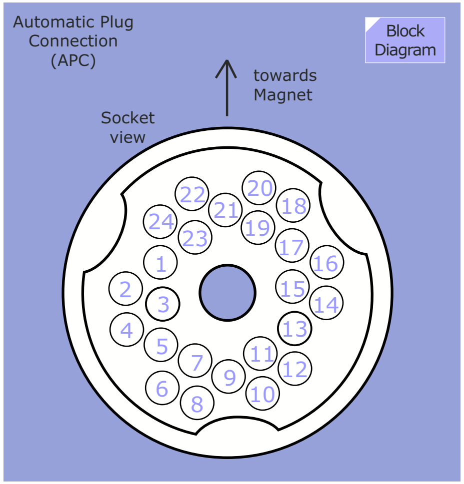


Trolley / RTT Switches

Swit ch	Location	Description	Status
S33	Support frame, foot end	Vertical collision avoidance: Obstacles (improperly docked trolley) below the tabletop carrier.	Sensor output is low when an obstacle is in the sensor's range (optical reflex sensor). The sensor supply voltage stops when the trolley is docked correctly (refer to S40).
S40	Support frame, docking bracket	Recognition whether the trolley is docked. The trolley guide bar interrupts the sensor's optical connection (reflex photoelectric barrier with triple reflector in the docking bracket).	Sensor output is high when the trolley is docked.
S41	Removable TableTop	Detection if the Removable TableTop is in vicinity to the trolley.	Switch is not actuated and switching contact is open, if the Removable TableTop is in the vicinity of the trolley.
S42	Removable TableTop, right side	Right side of trolley is touching the Removable TableTop. The APC must be fully connected at this position.	Switch is actuated and switching contact is open when the Removable TableTop touches the trolley (hooks can be closed in this position).
S43	Removable TableTop, left side	Left side of trolley is touching the Removable TableTop. The APC must be fully connected in this position.	Switch is not actuated and switching contact is open when the Removable TableTop touches the trolley (hooks can be closed in this position).
S44	Support Plate	Notification: Removable TableTop contact during upward travel at approx. 35 mm.	Switch is actuated and switching contact is open, if the support plate is in vicinity of the Removable TableTop.
S45	Support Plate	Removable TableTop touches the support plate. The APC must be fully connected in this position.	Switch is actuated and switching contact is open when the support plate touches the Removable TableTop (hooks can be opened in this position).
S46	Removable TableTop, left side	Left trolley hook is closed. The APC must be fully connected in this position.	Switch is not actuated and switching contact is closed, if left hook is closed.
S47	Removable TableTop, right side	Right trolley hook is closed. The APC must be fully connected in this position.	Switch is not actuated and switching contact is closed, if right hook is closed.
S48	Removable TableTop, left side	Left trolley hook is closed. The APC must be fully connected in this position.	Switch is actuated and switching contact is closed, if left hook is open.
S49	Removable TableTop, right side	Right trolley hook is closed. The APC must be fully connected in this position.	Switch is actuated and switching contact is closed, if right hook is open.
S50	Support Plate	Vertical collision protection for trolley. End stop for down movement with trolley connected.	Switch is not actuated and switching contact is closed, if the trolley does not touch the support plate.
S60	Jumper in APC of RTT	APC is connected (redundant to S45).	Contact closed when APC is properly connected.

Swit ch	Location	Description	Status
S61	Support Plate	Connector for vacuum cushions, headphones, alarm squeeze ball, and two foot end RF connectors (under lid) are disconnected. RTT may be separated.	Switch is not actuated and switching contact is closed, when connectors are disconnected. Switch is connected in series to S70 and S71.
S62	Jumper in APC of RTT	not used	n/a
S63	Jumper in APC of RTT	not used	n/a
S70	Support Plate, left side, foot end, coil plug X7	Coil plug cover open = coil connector X7 plugged.	Switch is not actuated and switching contact is closed when lid is closed, i.e. no coil plug connected to X7. Switch is connected in series to S61 and S71.
S71	Support Plate, right side, foot end, coil plug X9	Coil plug cover open = coil connector X9 plugged.	Switch is not actuated and switching contact is closed when lid is closed, i.e. no coil plug connected to X9. Switch is connected in series to S61 and S71.

Figure 112 *APC Socket*



PMU

Overview

Some cardiological and abdominal imaging techniques require physiological triggering for improved image quality and increased diagnostic value of the images. For example, when running a heart study it is very important to know, whether specific images have been measured during the diastolic phase (heart muscle relaxed) or during the systolic phase (heart muscle contracted). The system control unit which executes the measurement (AMC), uses the physiological triggering signals for acquiring image data according to the desired physiological state.

Physiological monitoring is also used to monitor the patient’s well-being.

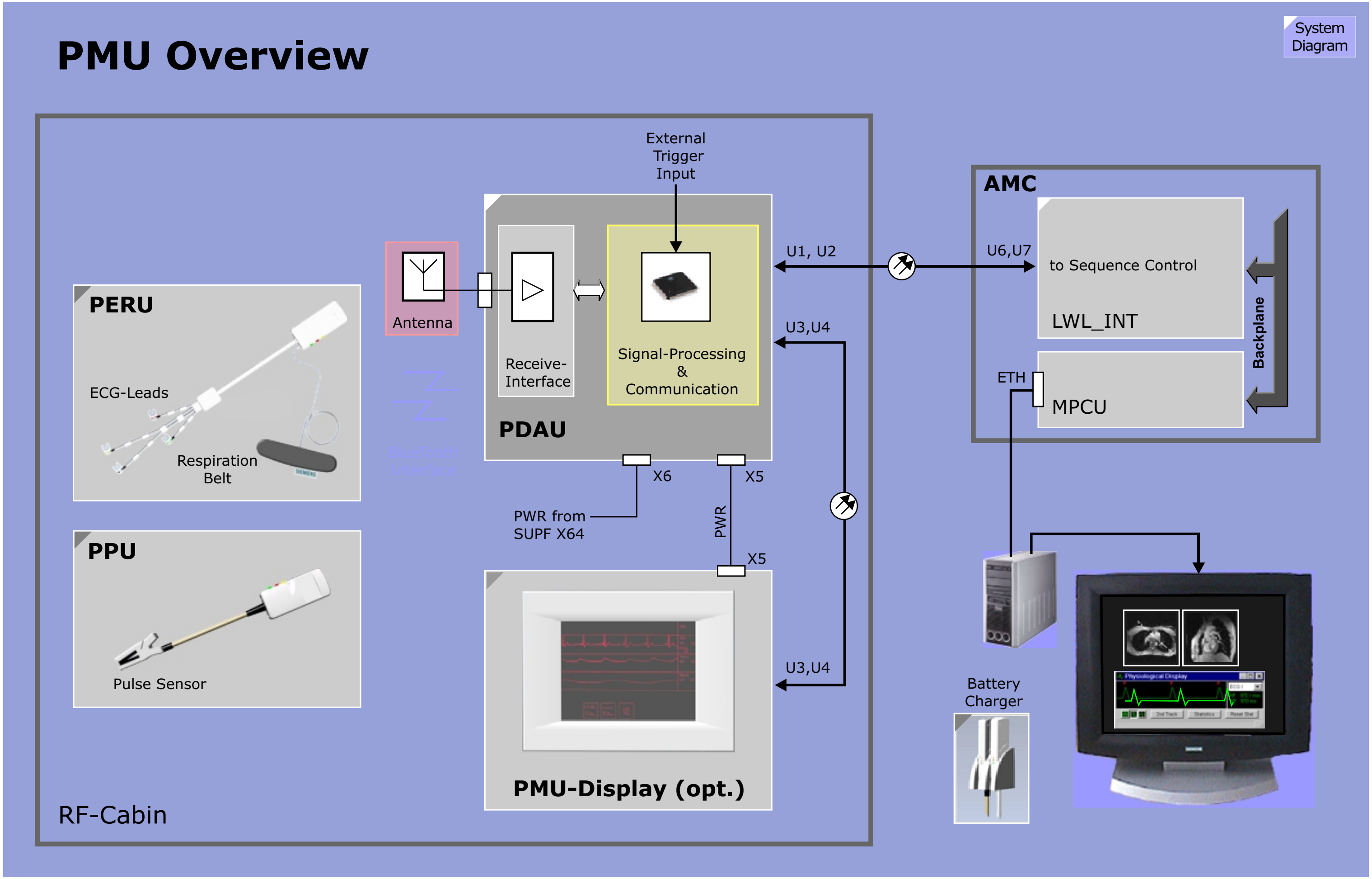
Physiological signals available for triggering:

- Electro-Cardio Gating (ECG)
- Respiratory (chest movement)
- Pulse (heart rate)
- External triggering source (TTL input)

The PMU consists of the following components:

- **PERU** (a wireless Physiological ECG and Respiratory Unit)
- **PPU** (a wireless Peripheral Pulse Unit sensor)
- **Antenna** (to receive the PERU and PPU signals. Located at the top-right side of the magnet behind the front cover)
- **PDAU** (the Physiological Data Acquisition Unit receives and processes the triggering signals from the sensors)
- **PMU display** (a monitor for displaying the physiological signals at the magnet - an option)

Figure 113 *PMU Overview Diagram*



PERU

Function

The PERU (Physiological ECG and Respiratory Unit) is able to record two ECG signals and one Respiratory signal (detected by a connected belt) simultaneously. Both signals are digitized and transmitted wireless using the Bluetooth standard (a 2.472 GHz bi-directional physical layer transmission protocol). Maximum transmit power is 1mW with a usable transmission radius of about 3 meters.

The PERU is supplied by an integrated Lithium-battery that can be recharged in less than three hours by a wall-mounted charging station that is normally mounted close to the operator’s console.

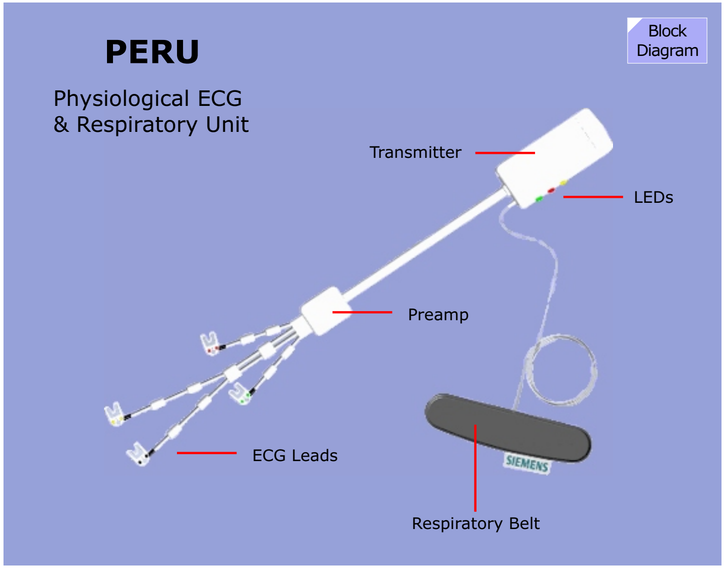
LEDs

LED	Description
green	Battery status (flashes two times rapidly if low)
red	Electrode error (flashes if electrode not correctly applied)
yellow	Charging status (off if charging cycle is finished)

Service Routines

The PERU is equipped with a built in test-signal generator that can be activated by starting the PMU-interactive test in SESO. The AMC sends a test command over the CAN bus (LWL_INT) to the PDAU and then to the PERU via the wireless Bluetooth connection. An internal test signal (3.2 Hz) is connected to the preamplifier and routed back the same way to the AMC, from where it is fed to the Physiological window in *syngo* MR.

Figure 114 *PERU*



PPU

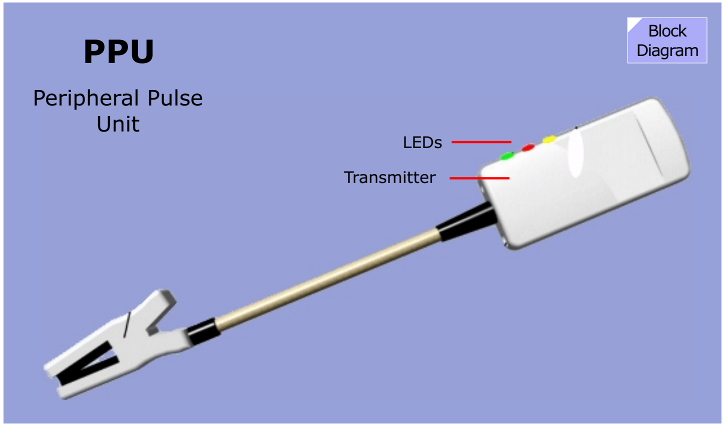
The PPU (Peripheral Pulse Unit) detects the peripheral pulse of a patient by means of a fibre-optic finger clip. The signal is converted into an electrical pulse, digitized and transmitted via the second channel (2.474GHz) of the Bluetooth wireless interface. Maximum transmit power is 1mW with a transmission radius of about 3 m.

The PPU is supplied by a integrated Lithium-battery that can be recharged in less than three hours by a wall-mounted charging station that is normally mounted close to the operator’s console.

LEDs

LED	Description
green	Battery status (flashes two times rapidly if low)
red	sensor error (flashes if pulse sensor not correctly applied)
yellow	Charging status (off if charging cycle is finished)

Figure 115 *PPU*

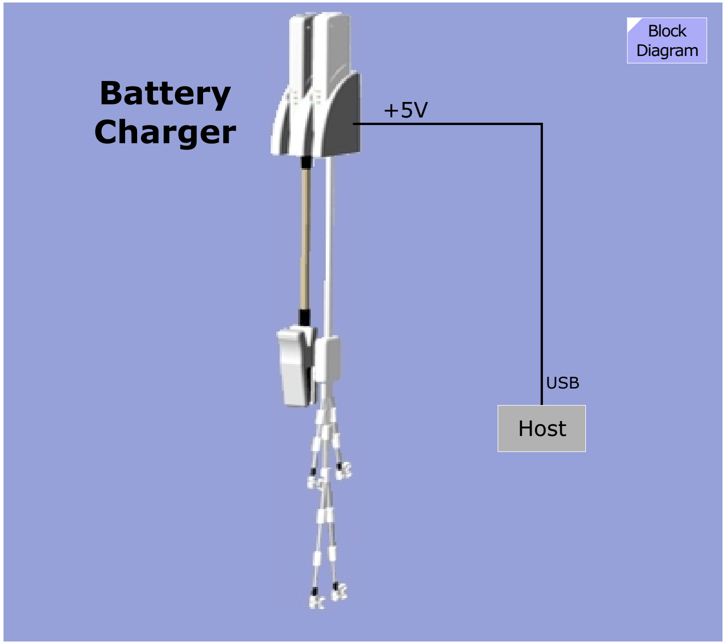


Battery Charger

A battery charger for PERU and PPU is delivered with the system. It can be wall-mounted and should be mounted close to the operator's console. The +5 VDC charging power is supplied by a cable connection from a free USB connector of the Host computer. Charging time for PERU and PPU battery is less than three hours. When the charging cycle is completed, the yellow control LEDs at PERU and PPU goes off.

If a PERU or PPU is stored for longer periods of time without being connected to the Battery Charger, it is recommended to connect the dummy plug (part of system delivery) to its charging connector to avoid battery discharging.

Figure 116 *Battery Charger*



PDAU

The PDAU (Physiological Data Acquisition Unit) receives the physiological signals from PERU and PPU, processes these and routes them via a bi-directional, serial fibre-optic interface to the AMC and PMU Display. The unit is mounted on top of the Control electronics and is supplied with power by the SUPF connector X64.

The receive-antenna for the physiological signals is located at the top-right side behind the front funnel cover and connected via coaxial cable to the PDAU.

For external triggering, the PDAU is equipped with two galvanically-isolated cinch-connectors that are accessible at the left side of the Lifting column cover. The trigger input (TTL-signal level) can be used to trigger a MR sequence, the trigger output can be fed to an external device.

The PDAU supply raw voltage (+24.0 VDC at connector X6) is generated by the SUPF A4120, as well as the 13.8 VAC voltage supply for the PMU Display.

Figure 117 *PDAU Layout*

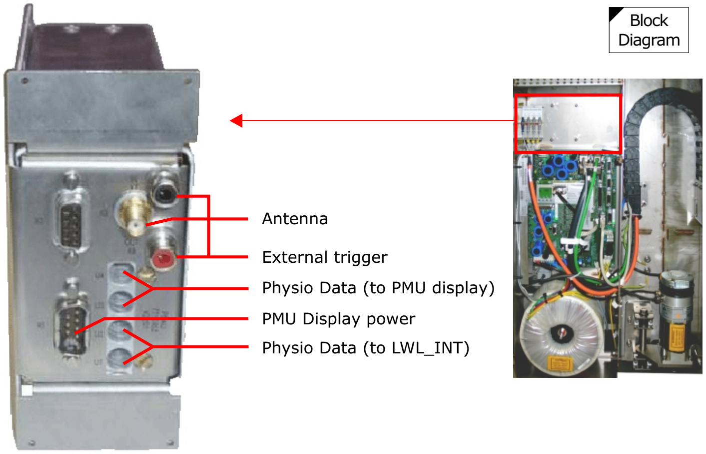
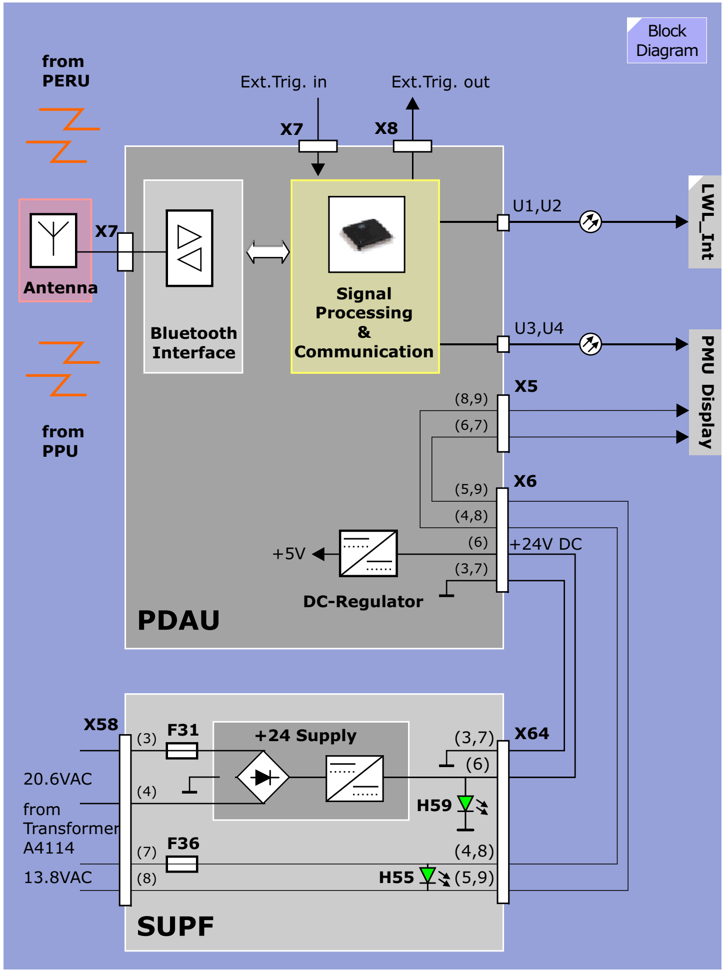


Figure 118 *PDAU Block Diagram*



PMU Display (option)

The PMU Display is able to display the Physiological signal curves inside the examination room to facilitate the correct positioning of sensors to the patient. The PMU Display is mounted at the top-left side of the magnet front cover.

A 13.8 VAC supply voltage for the PMU Display is derived by connector X5 at the PDAU. The bidirectional Fiber-optic interface (FOC-connectors U3 and U4) supplies communication to the PDAU.

Four signals can be displayed:

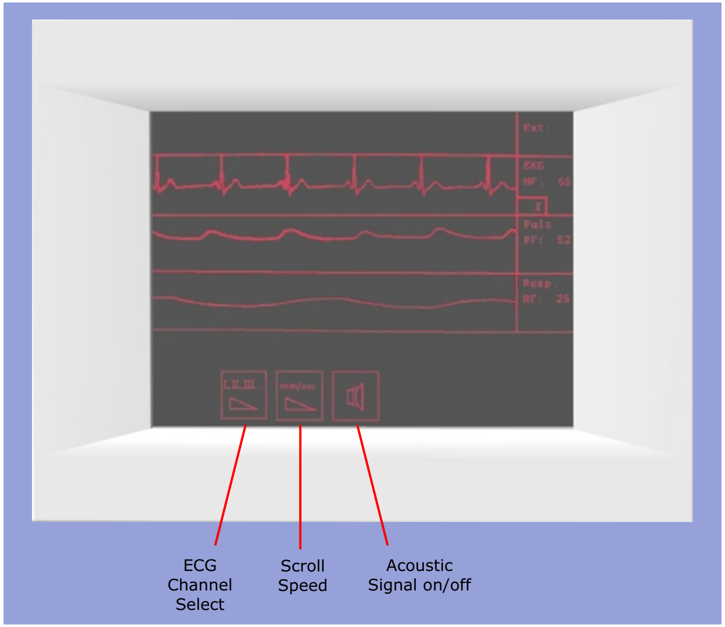
- **ECG**
- **Pulse**
- **Respiratory signal**
- **External Triggering signal**

ECG, Pulse and Respiratory signal are displayed simultaneously in real time curves, the External-Triggering signal is indicated as blinking "*" symbol for each low-to-high transition.

The PMU Display is equipped with three touchscreen buttons to adjust:

- **ECG Channel Select** (I or AVF for best R-wave signal)
- **Scroll Speed** (three speeds)
- **Acoustic Signal** (beeper activate/deactivate)

Figure 119 *PMU Display*



Intercom

Overview

The Intercom system contains the following standard components:

- **Central Unit Intercom**. This box is mounted at rear of the operator's console. An external audio source, e.g. CD player, can be connected at Music In input to allow piping in music to the patient. **R1** is a potentiometer to adjust the level of the speech from Control Room to RF cabin (Operator speaks) in order to avoid acoustic feedback when the door is opened, **R2** is a potentiometer to adjust the level of speech from RF cabin to Control Room (Patient speaks, Noise of Cold Head, Gradient Noise) to avoid acoustic feedback when the door is opened.
- **Operating Unit Intercom.** Contains a red table stop button on top. Pressing this button twice will stop a running sequence. For the functions see graphics on the right.
- **Two Microphones.** Located in magnet front- and back cover.
- **Squeeze Bulb (nurse call)**. Pressing the bulb causes an audible signal to sound on the Operating Unit Intercom.
- **Head Phone.** The patient can hear operator-announcements and music. Music is interrupted for announcements.
- **Loud Speaker**. Mounted on magnet frame, plays music and operator's announcements.

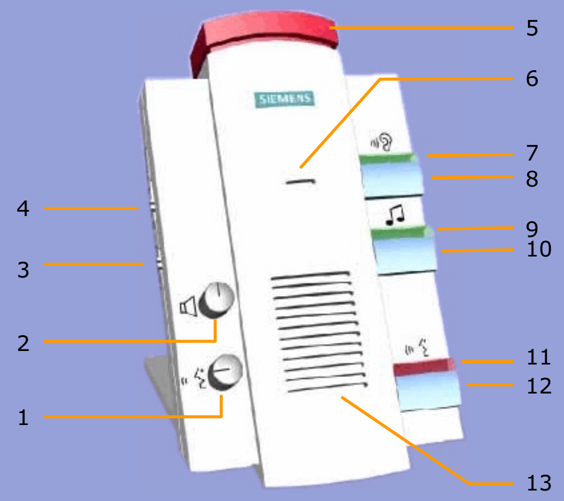
Additional options are:

- **CCD Camera.** At rear side of magnet. The image is transferred via fiber optic to the
- **Patient Monitor.** The monitor is adjustable, see description system documentation.

NOTE	Please refer to the Operating Manual for instructions on use.

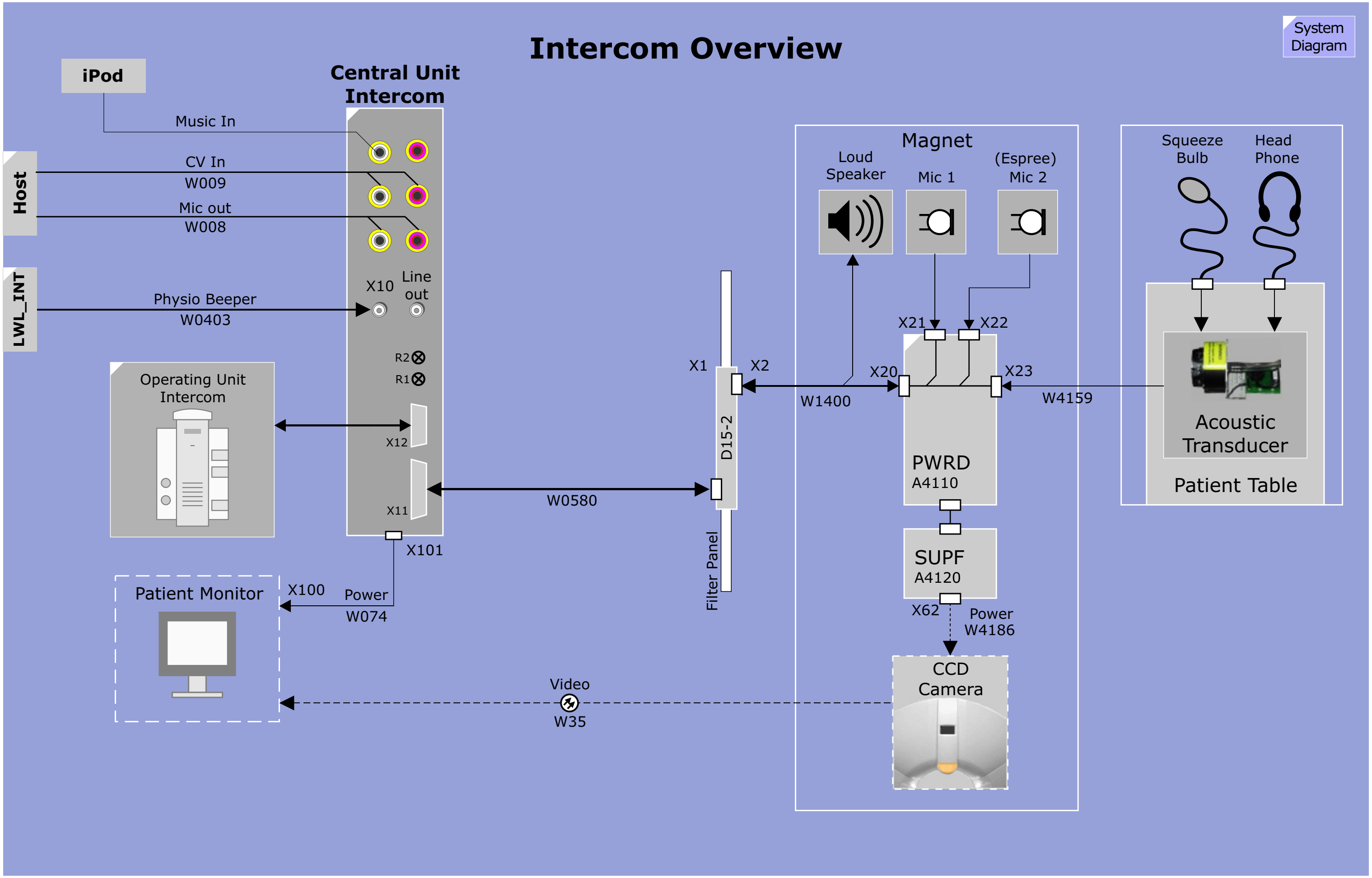
Figure 120 *Operating Unit Intercom*

Block Diagram



1) Volume in RF cabin (speech only)
2) Volume console (listening)
3) CV/CBT switch (Computer Voice or background music)
4) Physio beeper volume trigger (4 levels)
5) Table stop/sequence stop button
6) Microphone
7) LED listening is on
8) Button listening on/off
9) LED music on
10) Button play music in cabin on/off
11) LED squeeze bulb active
12) Speak button and squeeze bulb reset button
13) Loudspeaker

Figure 121 *Intercom Block Diagram*



Intercom Connections

General

The following figure shows the Intercom connections in detail.

Figure 122 Intercom Connections

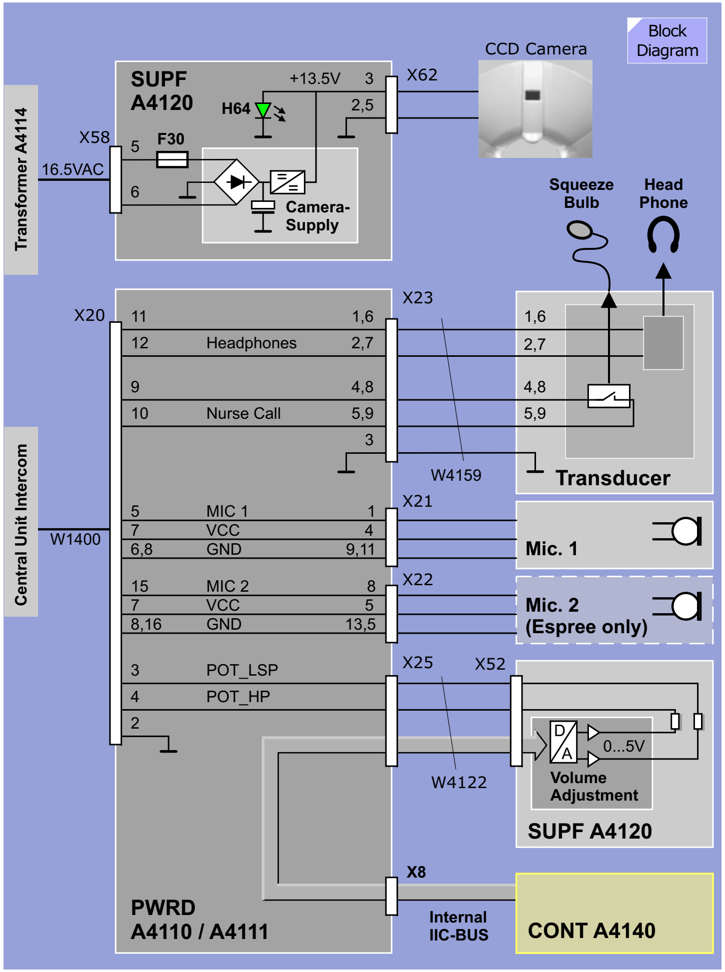
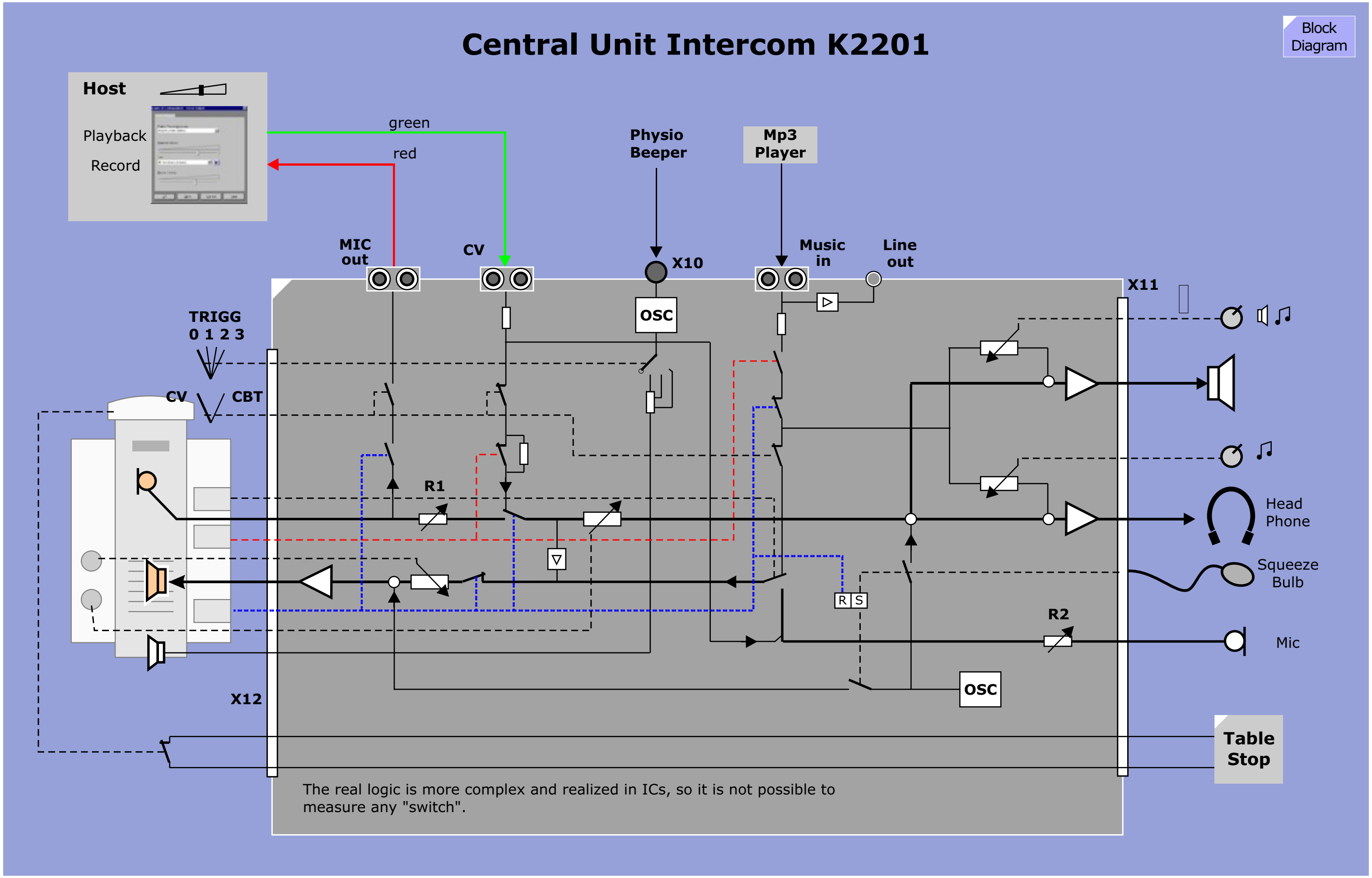


Figure 123 *Central Unit Block Diagram*



Section

7

Gradient System

Introduction

The Gradient System of the MAGNETOM Avanto consists of a switch mode current generators (amplifiers) and an actively shielded gradient coil. The power capabilities of both these components has reached new levels unparalleled in the industry anywhere until now.

The following description covers the **K2259 Gradient System**.

An overview of the Gradient System and each component is given followed by parts location diagrams showing the component assemblies and their location.

Gradient System Specifications

The K2259 gradient system used in the MAGNETOM Avanto/Espree is largely equivalent to the K2217 gradients of the existing MAGNETOM Symphony and Sonata systems. All components were redesigned to achieve even higher performance.

The performance values for the available gradient options are listed in the table below:

	Q	SQ	Z	DZ
Maximum Gradient field in mT/m (X/Y/Z)	33/33/33	40/40/45	33/33/33	33/33/33
Minimum Rise Time	264 µs	200µs	330 µs	194 µs
Slew Rate in T/m/s (X/Y/Z)	125	180/180/ 220	100	170
Maximum Gradient Current	460 A	625 A	625 A	650 A
Maximum Voltage	1250 V	2000 V	1200 V	2000 V
Gradient Coil	AS05		AS022 AS22SL	AS22SL

Gradient System Components

Gradient Amplifier

The Gradient System hardware components consist of eight functional blocks:

- Gradient Small Signal Unit (GSSU)
- GSSU-Power Supply (GSSU-PS)
- Power Stage Supply
- Power Stage (3x)
- Output Filter Chokes
- Fan Box
- Current Converter Unit (CCU)
- Gradient Coil Assembly

Gradient Coil Assembly

The Gradient Coil Assembly consists of the active-shielded water-cooled gradient coil and five integrated high-order shim coils for active shimming and pockets for shim trays for placing shim-iron plates for the passive shim. All connections are at the rear side of the magnet.

The gradient coil for the Espree comes in two variants:

Coil	Description
AS 022	The gradient and RF Body coils are integrated into a one-coil design. Shim trays are accessed from the BACK of the coil.
AS022SL	Slim Line 70. Gradient coil-only design. RF Body coil no longer integrated. Shim trays are accessed from the FRONT of the coil. This coil is in production since Sept. 2005.

Figure 124 *Gradient System K2259*

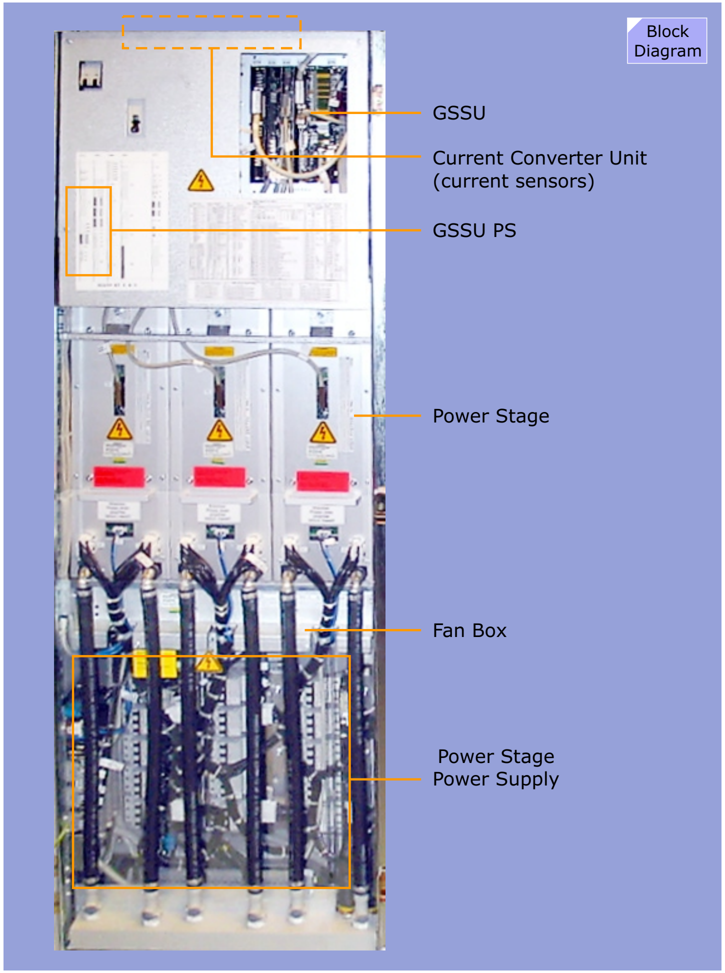
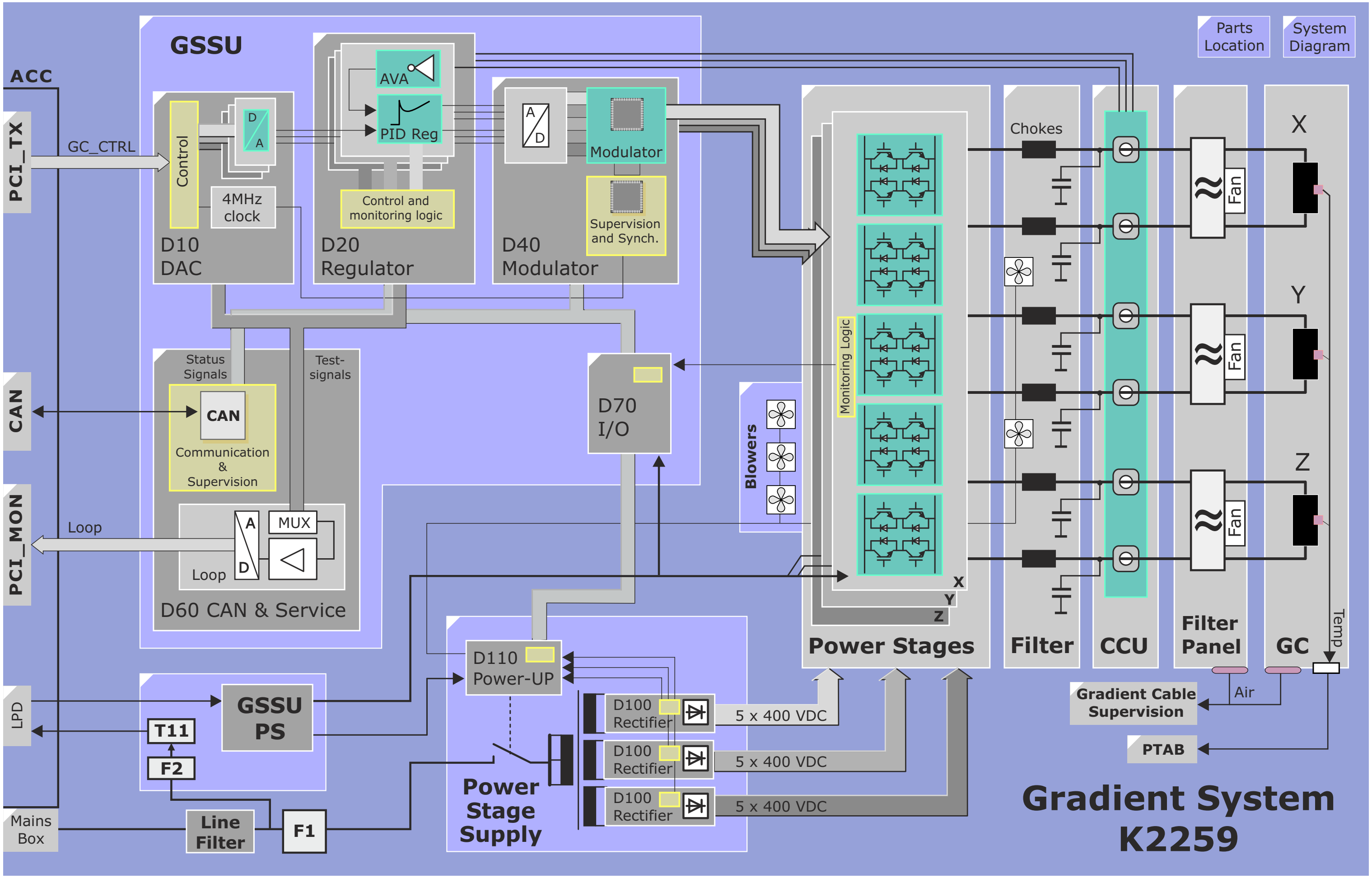


Figure 125 *Block Diagram of the Gradient System K2259*



Gradient Small Signal Unit (GSSU)

Overview

The GSSU consists of the five boards responsible for generating the pulse-width modulated control signals for the switches in the Power Stage based on the digital data supplied by the AMC. It's additional task is the overall supervision of the GPA.

The GSSU consists of the following PCBs or FRUs (Field Replaceable Units):

- Assembly Carrier
- DAC D10
- Regulator D20
- Modulator D40
- Service/CAN D60
- I/O-Board D70

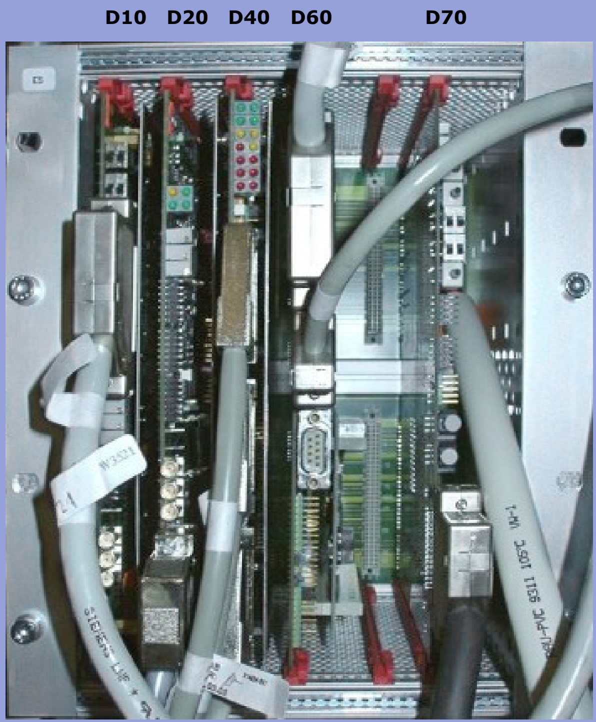
Assembly Carrier

The Assembly Carrier consists of the mounting rack for the GSSU-boards and the backplane D80 that provides interconnection between the GSSU components. A fan is built-in on top the Assembly Carrier.

NOTE The complete Assembly carrier is a Field Replaceable Unit (FRU).

Figure 126 *GSSU Front View*

Block Diagram



D10 DAC

Function

The DAC-board contains the DA convertors for all three X, Y, and Z channels. The digital data supplied by the AMC contains the gradient pulse amplitude data including the eddy current pre-distortion and the gradient delay. After the data are converted into analog signals they are sent to the Regulator D20 as the nominal current value.

Additionally, a 4 MHz clock signal (from AMC) is sent to the Modulator D40 for where it is used to synchronization the gradient.

Control Logic

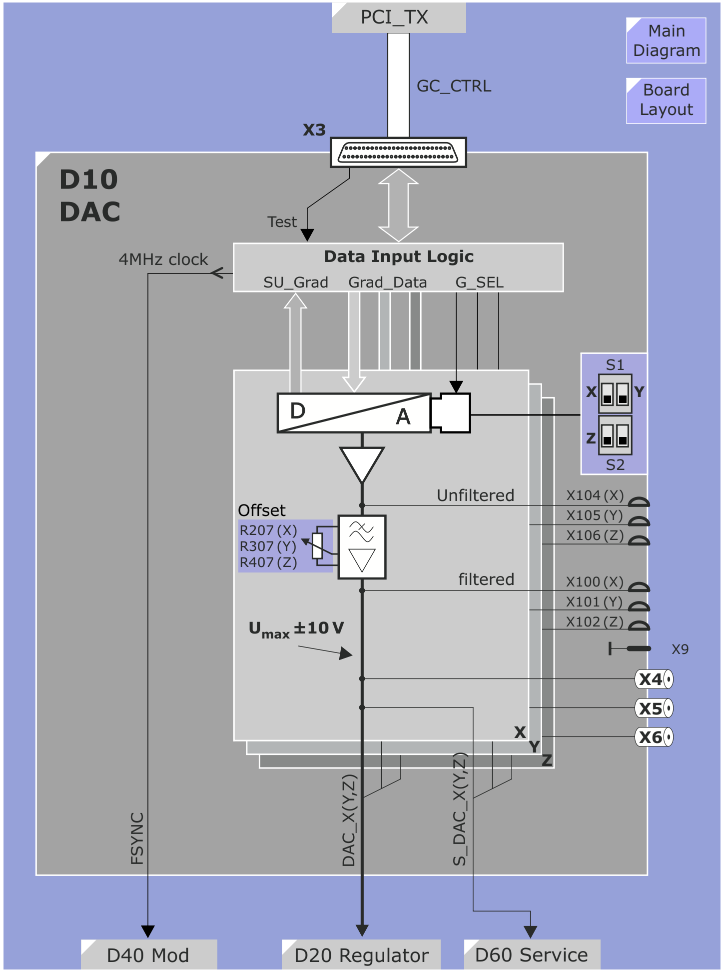
The gradient amplitude data (including the eddy current pre-distortion and the gradient delay) coming from the AMC is connected to a 50 pin female front connector (X3). The Control Logic contains circuitry to galvanically isolate from the AMC, *data change recognition* and a data feedback for test looping. For the detailed description and the timing of the gradient control data refer to the AMC-description.

The 20 bit amplitude data (**GRAD_D**) for the three gradient axes is transferred multiplexed. The select signals **G_SEL** are used to clock in new gradient data values. Unchanged values are not clocked in, thereby increasing the signal stability.

Input Loop-back Test

An input data loop-back test between the PCI_TX (in the AMC) and the D10 can be run from the Service Software. When the **Test** signal is activated (SeSo), the 20 bit data of the X channel (**SU_Grad**) and the control lines can be looped back to the PCI_TX to verify the data path.

Figure 127 *D10 DAC*



Nominal Value

The main DAC output is fed over the GSSU backplane to the D20 Regulator board as the nominal gradient amplitude. A copy is also sent to the D60 CAN & Service board where it is used as a feed back to the measurement control for loop testing and for the tune up procedures found in the Service Software.

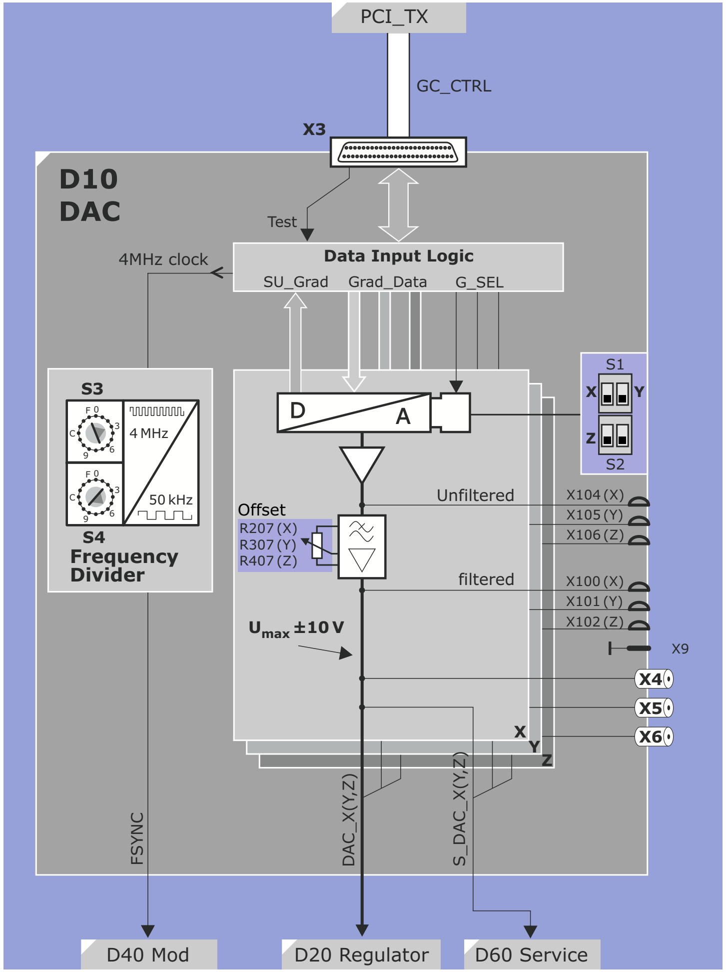
The output voltage of the DACs (DAC_X, Y, Z) is ± 10 V at full scale. It corresponds to the maximum gradient current that is configured by the GPA software license.

Offset Adjustment

Switches **S1** and **S2** are used to zero the DAC inputs and outputs e.g. for the offset adjustment in the factory or for advanced troubleshooting. When set to the upper position, the nominal value for the corresponding gradient axis is set to zero.

The offset potentiometers **R207**(X), **R307**(Y) and **R407**(Z) are adjusted in the factory.

Figure 128 *D10 DAC (switch setting for K2217 upgrades only)*



Switches

The switches **S1** (left/right) and **S2** (left) are used to set the DAC inputs to zero. This is necessary for Offset Adjustment using the potentiometers R207(X), R307(Y) and R407(Z).

Switch	Description	Position
S1 left	DAC_X enable/disable	down/up
S1 right	DAC_Y enable/disable	down/up
S2 left	DAC_Z enable/disable	down/up
S2 right	not used	not used

Test Points

The DAC output signals (DAC_X, Y, Z) are available for monitoring via QLA-connectors (X4, X5 and X6) and test pins (X100-X102 and X104-X106; GND on X9) at the front panel of the board.

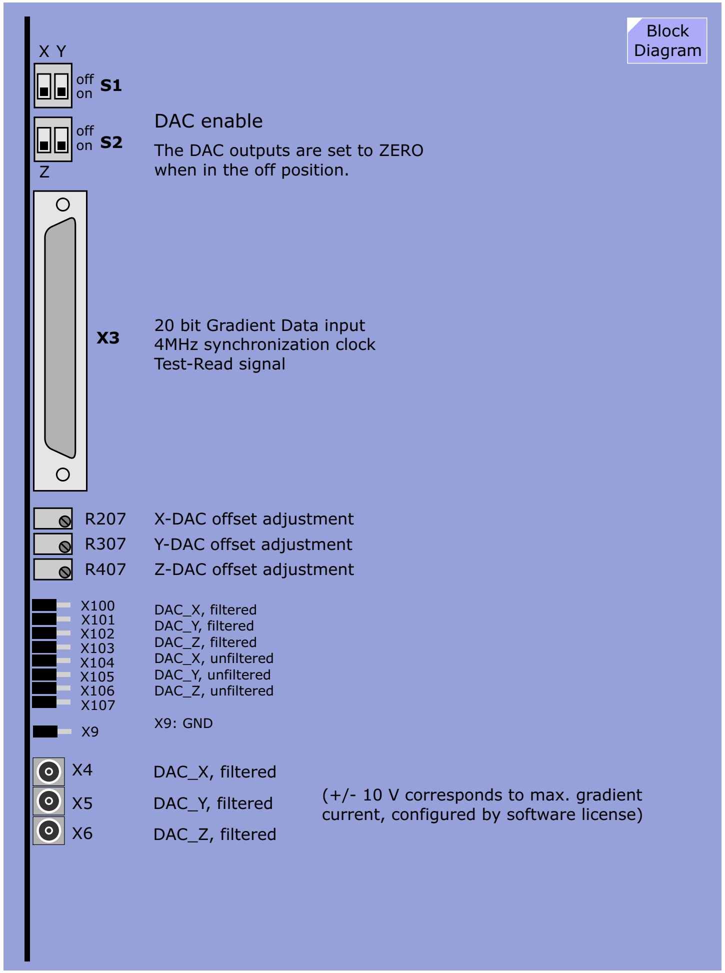
Potentiometers

The static DAC or cabinet -offset can be adjusted to zero with help of three potentiometers. This is pre-adjusted in the factory.

See "Offset Adjustment", page 174.

Potentiometer	Description
R 207	DAC_X offset adjustment
R 307	DAC_Y offset adjustment
R 407	DAC_Z offset adjustment

Figure 129 *D10 Front View*



D20 Regulator

Overview

The Regulator-board includes the regulator function for all three axes. It contains the following functions:

- Actual Value Amplifier
- PID-Regulator
- Supervision Logic
- Monitoring and LEDs
- Regulator Parameter Control

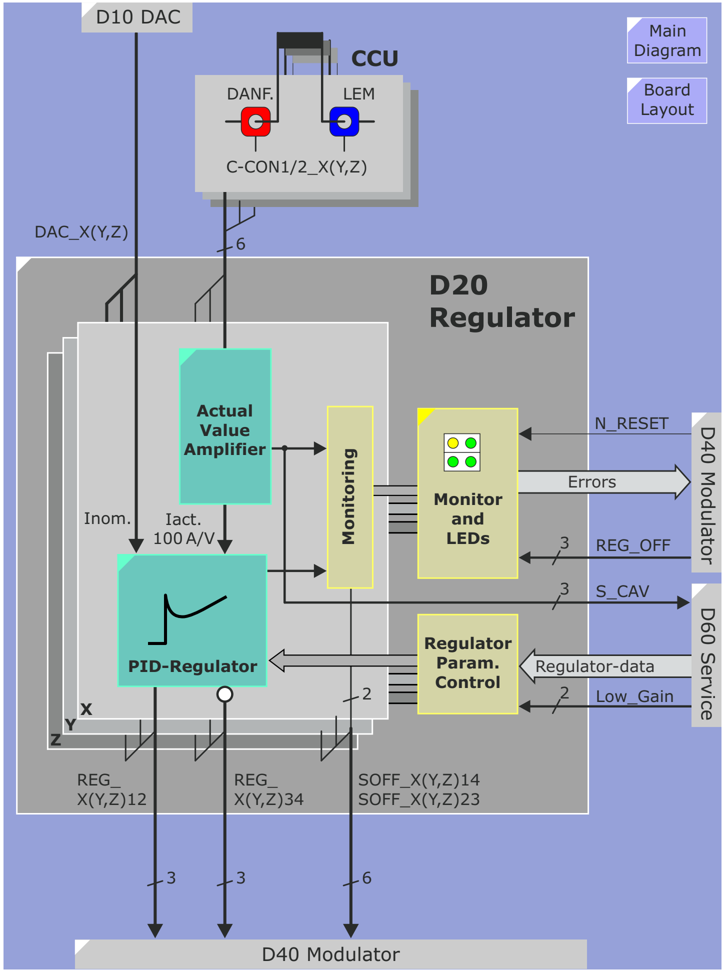
Actual Value Amplifier

The DANFYSIK current sensors in the Current Converter Unit (CCU) deliver a current that is proportional to the current driven through the gradient coil. The division ratio is 1:1750. That current is converted to a corresponding voltage level by the actual value amplifier (1 V corresponds to 100 A in the coil).

PID Regulator

In a PID-regulator the actual current value is compared to the nominal current value DAC_X(Y, Z) from the DAC-board. The resulting regulator difference is amplified by the regulator according to its characteristics. The output signals REG_X(Y, Z)12 and REG_X(Y, Z)34 of the regulator are connected to the input of the modulator board D40. The numbers 12, 34 of the signals indicate the final stage transistors that are controlled.

Figure 130 *D20 Regulator Block Diagram*



Function

Actual Value Amplifier (AVA)

The **C-CON1_X**(Y,Z) signal from the DANFYSIK Hall device is amplified on the D20 to achieve a precise **100 A/1 V signal ratio**. The amplifier has **offsets** adjustments potentiometers R155(X), R189(Y) and R223(Z) for the amplifier offset compensation. Switches S3 and S4 on the D70 can be used to disable the modulator outputs for service procedures.

The **C-CON2_X**(Y,Z) signal from the LEM Hall device is only used for monitoring purposes and is not amplified.

Offset Adjustment

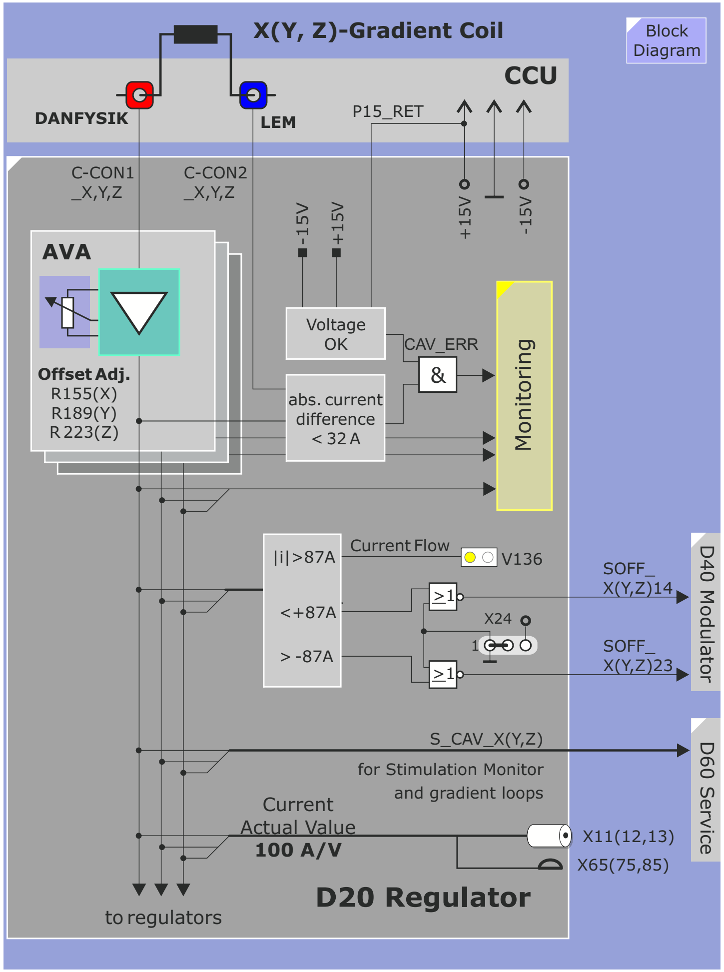
The offset of the amplifiers are factory adjusted with potentiometers R155(X), R189(Y) and R223(Z).

Outputs

The AVA's main output signal CAV is used for the regulation. A copy (**S_CAV_X**(Y, Z) is sent to the D60 CAN & Service board where it is digitized and sent to the PCI_MON in the AMC for peripheral nerve stimulation monitoring. In case the slew rate exceeds critical values the PCI_MON switches off the gradient current (see D40 and D60 description). The same signal is also used to evaluate the gradients in the Tune-Up and service test procedures (gradient loops).

The current actual value (or Iact) is available at the front side over QLY connector X11(12,13) for service procedures.

Figure 131 *D20 Actual Value Amplifier*



Monitoring and LEDs

The DANFYSIK and LEM outputs are compared, if difference is less than 32 A there is no error.

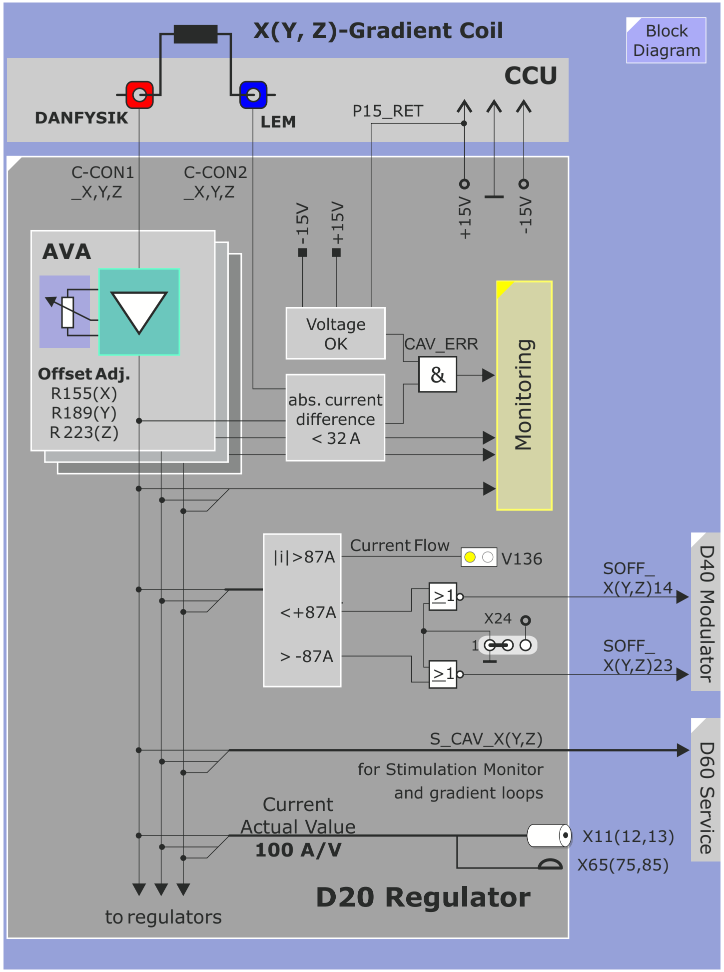
The power for the DANFYSIK and LEM devices (±15 V and ANA_GND) is supplied by the D20-board and the +15 V is looped back as P15_RET-signal for monitoring. The ±15 V supplies are also monitored.

If any of the above monitored signals indicates a fault, the respective current actual value error **CAV_ERR_X**(Y, Z) is sent to the D40-board to disable the modulator (for description of other errors and LEDs see D20 monitoring description).

Cross-current Protection

The actual value is monitored for a threshold of approximate 87 A absolute. If the current is higher, the signal **SOFF**_X(Y, Z)14 disables the positive current direction and the signal SOFF_X(Y, Z)23 disables the negative current direction at the modulator board D40 as indicated by LED V136 (lights up).

Figure 132 *D20 Actual Value Amplifier*



PID-Regulator

The nominal value sent from the DAC-board is inverted and added to the actual value coming from the AVA. The signal is fed into a closed loop regulation circuit, based on a digitally controlled 7-bit PID-regulator (P = proportional, I = integral, D = differential part).

Regulator Parameter Control

The initial setting of the regulator after power on is determined by DIP-switches S1 to S9 (see table below). The setting of switch 8 (off-position) on switch S3, S6 and S9 determines if this initial hardware setting can be overwritten by software via the D60. In that case, the downloaded site-specific regulator parameters from Tune-up are activated.

The regulator output signal is sent to the D40-board (inverted and non-inverted).

Regulator Default Settings

For setting of switches S1-S9 for the regulator parameters please refer to diagrams, jumper list section.

Axis	P	I	D
X	S1	S2	S3
Y	S4	S5	S6
Z	S7	S8	S9

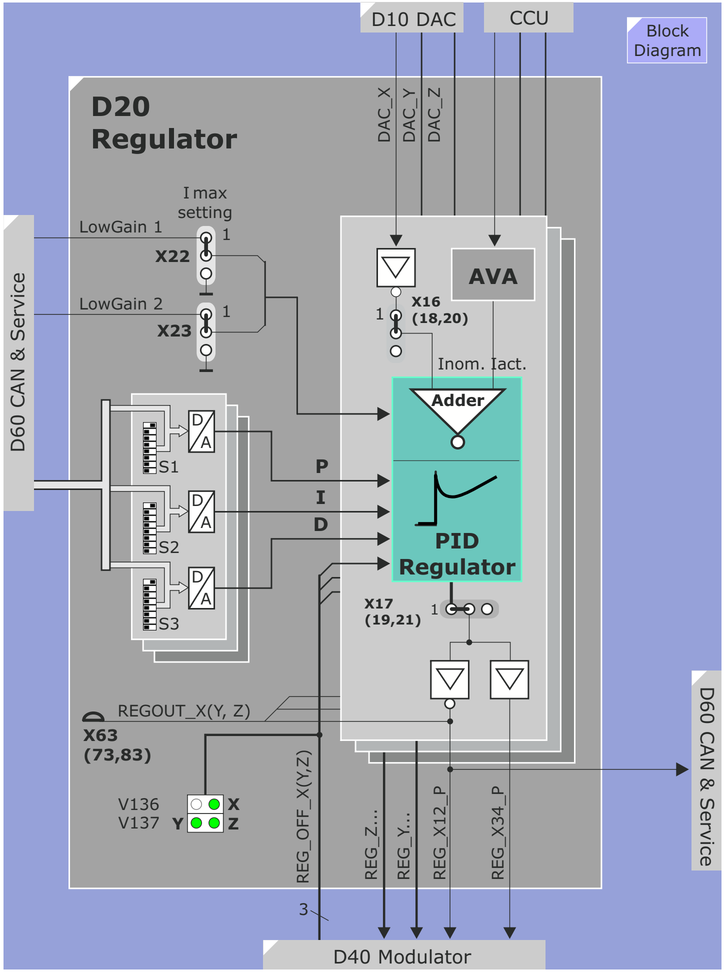
Gain Scaling

The Low Gain1 and Low Gain2 signals are used to scale the gain of the amplifier according to the max gradient performance level:

LG1	LG2	Performance
0	0	not used
1	0	not used
0	1	550 A (Q-engine)
1	1	650 A (Z, DZ, SQ-engine)

The LEDs for these signals are found on the D40 board.

Figure 133 *D20 PID-Regulator*



Monitoring

The following table shows the monitoring on the D20-board:

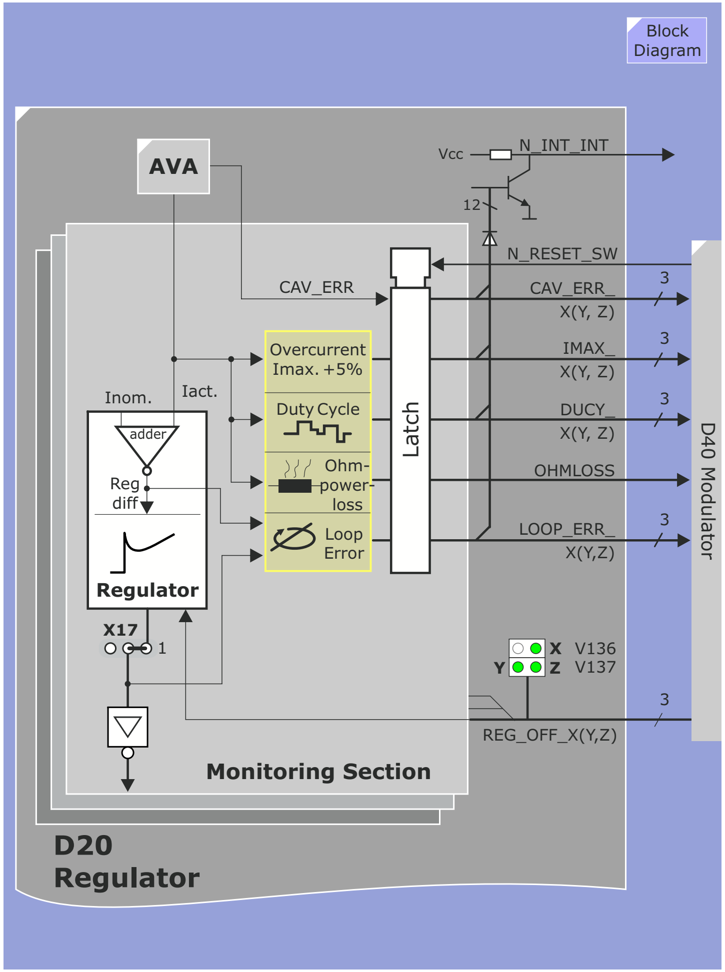
Error	Description
Over-current	Occurs when the gradient output current exceeds 5% of the maximum allowed output current.
Duty Cycle	A monitoring designed to prevent excessive IGBT heat development in the millisecond range.
Ohm power loss	I^2 measurement designed to prevent overheating of the cables and gradient filter (on the filter panel) in the minute range.
Regulation (loop) error	Occurs when the difference between I_{nom} and I_{act} becomes too high (indicating a break in the regulation loop) or when the Regulator output signal is too high (indicating a regulator malfunction)
CAV-error	current sensor difference >32 A 15 V return from current sensor; ±15 V supply

All of the above mentioned errors are reported to the D40 modulator-board. From there, the D60 CAN & Service board is informed about the error condition.

Regulator Enable

The modulator board D40 uses the signal **REG_OFF**_X(Y, Z) to disable/enable the regulator board. The enable status is shown by three green LEDs on the front panel of the D20-board.

Figure 134 *D20 Monitoring*



LEDs

LED	Description
V136 left	current flow (one or more axes) > |87 A|
V136 right	regulator X enabled
V137 left	regulator Y enabled
V137 right	regulator Z enabled

Test Points

Refer to sticker inside Gradient cabinet.

Potentiometers

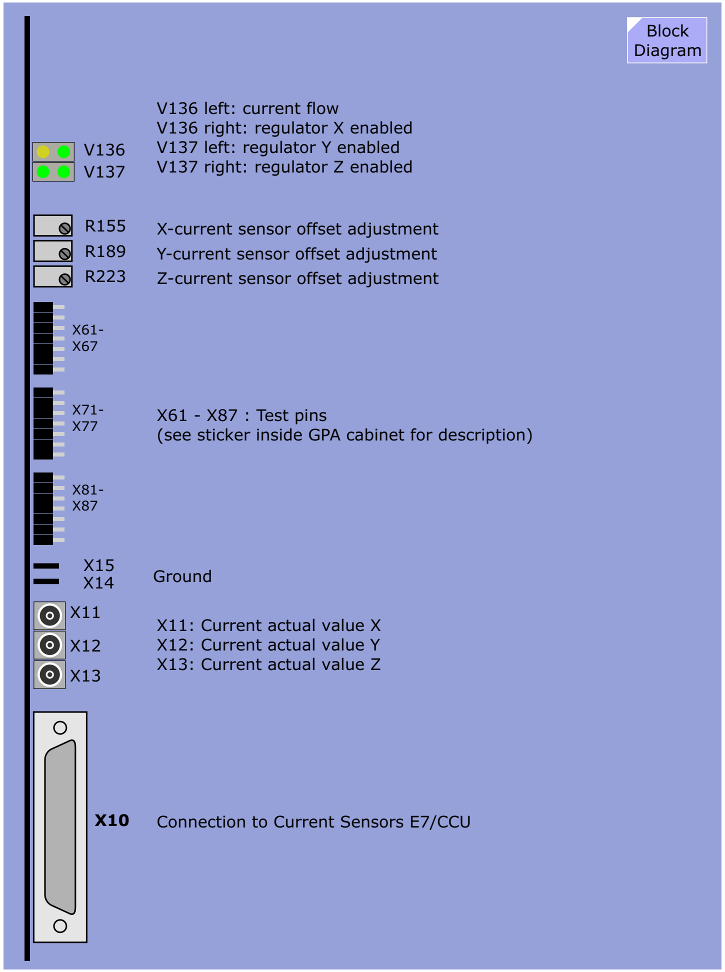
Potentiometer	Description
R155	X-current sensor offset adjustment
R189	Y-current sensor offset adjustment
R223	Z-current sensor offset adjustment

Jumpers

Jumper	Position	Description
X22/23	1-2/ 1-2	Current scaling is determined by software over the D60: Q = 550 A, Z, DZ, SQ = 650 A
X24	1-2	opposite current direction on D40 modulator is blocked by disable logic

Jumpers X16-21 have to be set to position 1-2 for normal operation.

Figure 135 *D20 Front View*



D40 Modulator

Function

The following main functions are implemented on the Modulator board D40 K2259:

- **Modulation** - generation of pulse-width-modulated switching signals for the three axes
- **Supervision** circuit of time critical power stage related signals
- **Synchronization**
- **Power-up Control**

Pulse Width Modulator

The D40 board is based on a programmable logic. The D20 Regulator output signals **REG_X(Y, Z)_12(34)** are analog-to-digital converted and fed to the modulator chip where the pulse-width-modulation takes place. The switching frequency is 20 kHz. It is synchronized by another 20 kHz clock signal that is decided from the 4 MHz **FSYNC** by a programmable frequency divider. The switch-signals (low-active) for the power stages are fed out by three front plugs.

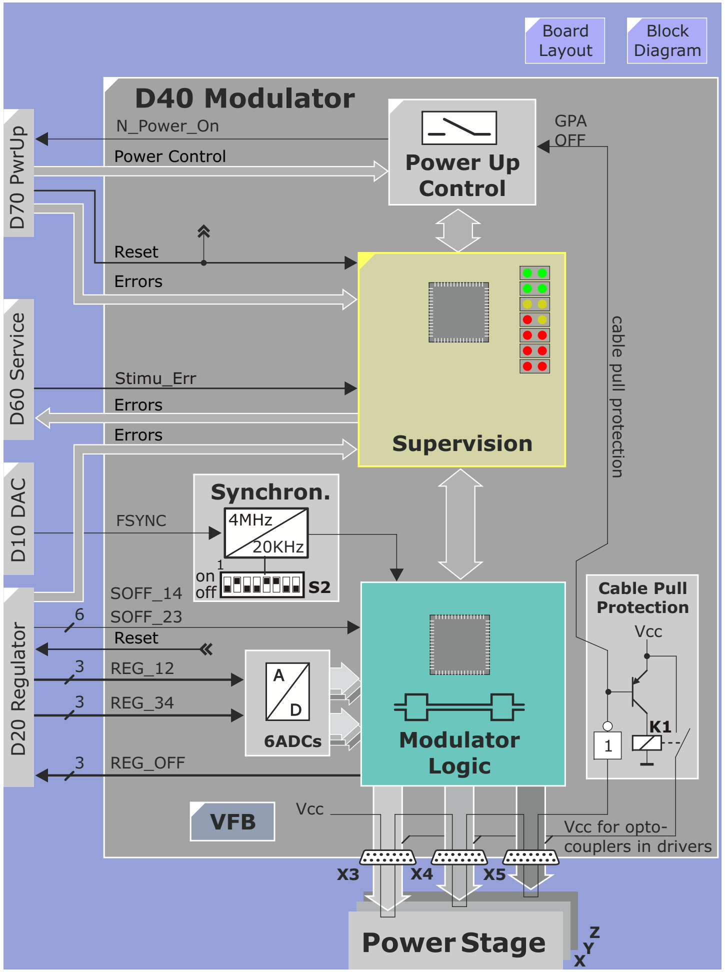
By means of a standard SCSI-cable (it is not a SCSI-bus!) the signals are connected to the Power Stage modules. The proper connection of those cables is monitored by a wire bridge.

The D20 regulator-board is able to report errors to the D40 modulator. In case of an error, the D40 can disable the corresponding regulator axis by means of signal **REG_OFF_X(Y, Z)**.

Slew Rate Adjustment

The maximum possible slew rate of the gradient system is adjustable by setting limits for the pulse-width modulator. The setting of jumper **X10** and **X11** determines if software limits from the D60 or fixed values from the board itself are used (see jumper list).

Figure 136 *D40 Modulator*



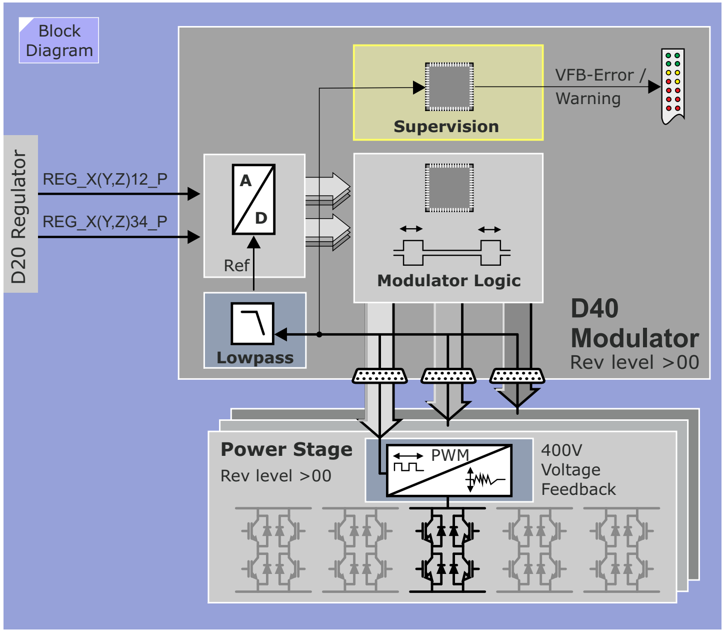
Power Stage Voltage Feedback (VFB)

Gradient power stages and D40 modulator boards with "revision level > 00" are equipped with a final stage supply voltage feedback circuitry that controls the pulse width of the modulator chip. By these means, the negative effects of a fluctuating 400 VDC supply voltage on the gradient current stability are largely eliminated. The compensation works for PS voltage levels from 250-450 VDC. Outside that range or if the feedback voltage is faulty, an axis-dependent voltage feedback (VFB) error is generated.

A D40 modulator board with "rev. level > 00" cannot be combined with GPA power stages showing a "Rev. level = 00" since the feedback circuitry would be missing. All other combinations will work properly.

NOTE For systems with serial number <**25097**, the original D40 and Power Stages have rev level 00. In the event the D40 needs to be replaced the new one *will* have rev. level 01 or higher. In this case, you must also order three new Power Stages, if they are the original rev 00 ones, since rev level 00 Power Stages will not work with rev level 01 D40 boards!!! Power Stages with rev level 01 work fine with D40 boards with rev level 00.

Figure 137 *D40 Modulator VFB*



Supervision, Display, Synchronization

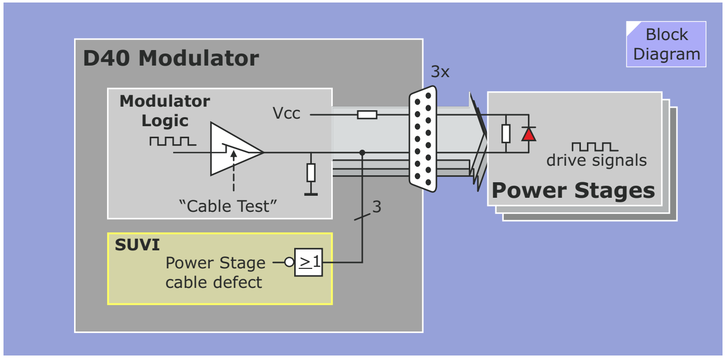
Voltage Monitoring

The D40 has a built-in internal monitoring for its supply voltages (±15 V and +5 V = VCC).

Modulator Logic Monitoring

- **Oscillation**: Regulator loop oscillation with more than 10.5 kHz
- **Clock fault**: The modulator logic monitors the presence of the 164 MHz internal clock.
- **Wrong controlling signal**: The proper timing and logic status of the Power Stage control signals is checked permanently (e.g. the two transistors of a half-bridge must not be switched on at the same time). In case of a problem, the "wrong controlling signal" stops modulator switching to avoid damage to the Power Stages.
- **Modulator defect**: The "clock fault", "wrong controlling signal" or any missing supply voltage will result in a "modulator defect" error, indicated by the red LED (V123, left).
- **Cable pull protection**: A wire bridge between pins 1 and 50 of the "SCSI"-plug in the Power Stage modules is used to check the proper connection of all plugs. The 5 V (VCC) control signal is looped via all connectors. When interrupted, the VCC-supply for the opto-transmitters in the Power Stage’s driver boards is switched off and the "Cable pull protection" error is generated.
- **Power Stage cable defect**: During GPA power-up, the modulator logic checks the function of the output stages and the cable connection to the Power Stages by switching the output shortly (0,5 sec.) to "high impedance". The monitoring at the SUVI will measure "high level", but in case of a faulty modulator output or a broken wire "low level" across the 20 kΩ pull-down resistor. A "Power Stage cable defect" error is generated as a result.

Figure 138 *Power Stage Cable Test*



SUVI

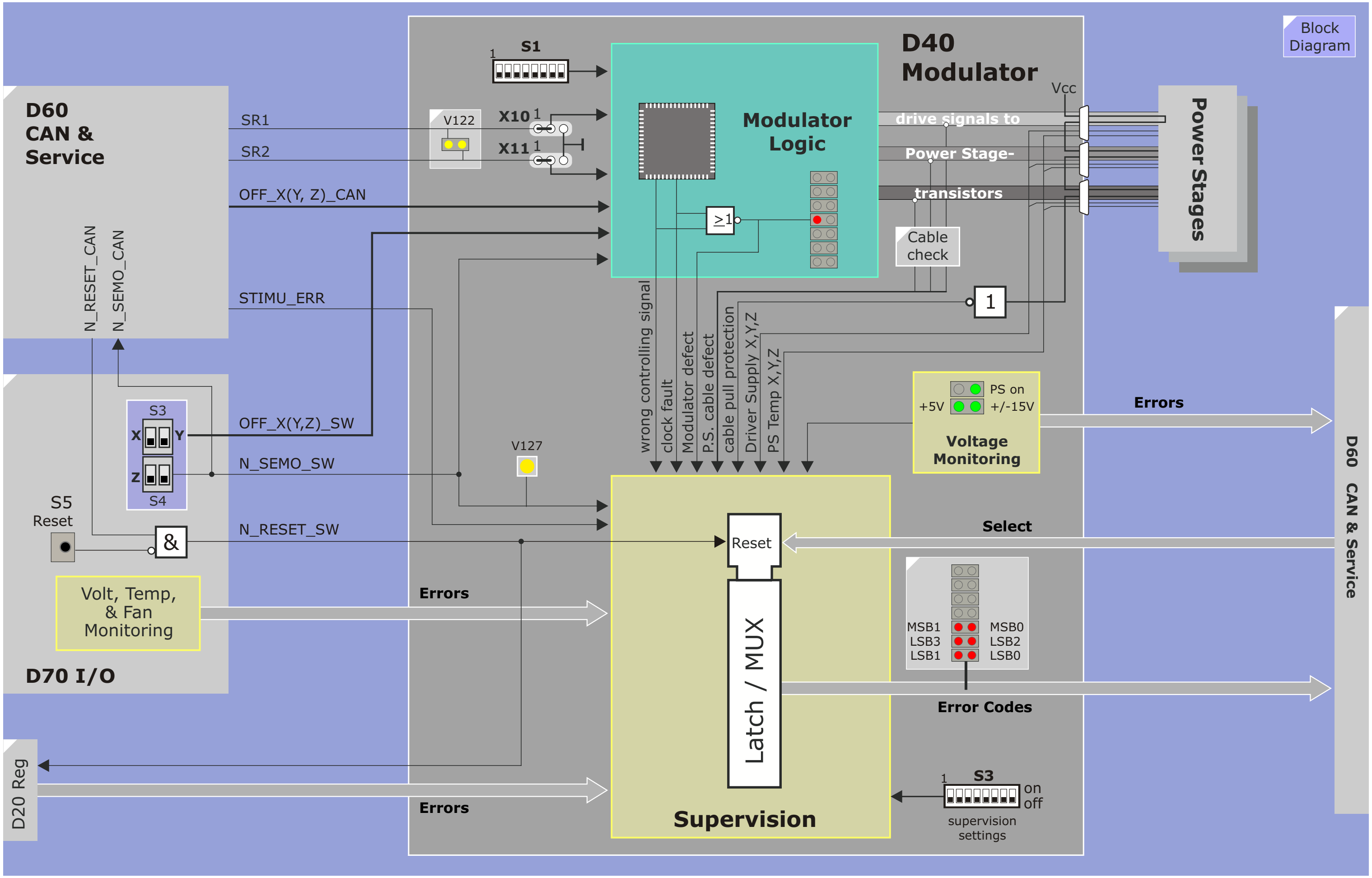
The supervision logic (SUVI) reports the errors generated by the Modulator logic and handles the following additional errors:

- **Synchronization fault**: (20 kHz sync. not ok)
- **All regulator errors**: reported by the D20 Regulator Board.
- GPA and gradient coil **temperature**, GPA **Voltage** and **Fan** monitoring: reported by several monitor circuits via the D70 I/O board
- **Stimulation errors**, reported by the Software Stimulation Monitor (PCI_MON in the AMC)

The SUVI error control-logic can report 64 different error codes. These are addressed by the D60 board with Select lines. The error code is read out and displayed by 6 red LEDs at the front side of the board (see LED description). A warning or error message is generated and fed to the D60 board.

The SUVI can generate three different types of fault classes which will be treated in greater detail in the LED description.

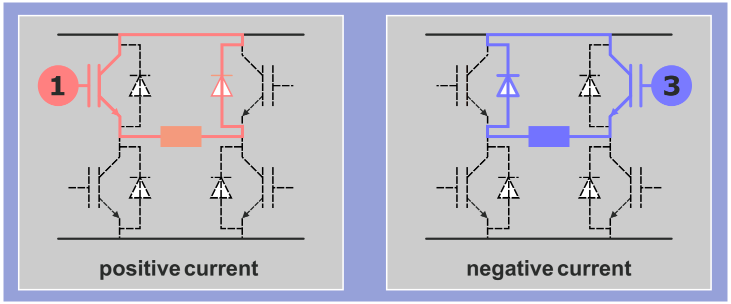
Figure 139 *D40 Supervision, Display, Synchronization*



Switch Off Modes

In case of an error, the modulator can disable a running gradient current in three ways:

- **"Hard" stop**: all switches of the Power Stage are blocked (e.g. VCC-error, wrong control signal error...).
- **"Soft" stop**: any gradient current will be ramped down over switches 1 and 3 of the Power Stage via upper free-wheeling (e.g. Imax., DUCY, synchronization error, coil temp. error, stimulation error...)



- **Power-off** the Power Stage supply (e.g. Power Stage supply over/under voltage...)

Modulator Disable

The modulators can be disabled with service switches S3, S4 on the D70 (**OFF_X(Y, Z)_SW**) or by software **OFF_X(Y, Z)_CAN** signal from D60 board). Both cases will result in a "hard switch-off" of the gradient current.

Reset of Errors

All errors can be reset by the processor D60 (**N_RESET_CAN**) or manually by push button **S5** at the I/O-board D70.

Service Mode

To facilitate troubleshooting, the GPA can be switched to Service Mode by a switch (S4 right at D70 in upward position) or by software via the **N_SEMO_CAN** signal from D60 CAN & Service board.

The following functions are affected by the Service Mode:

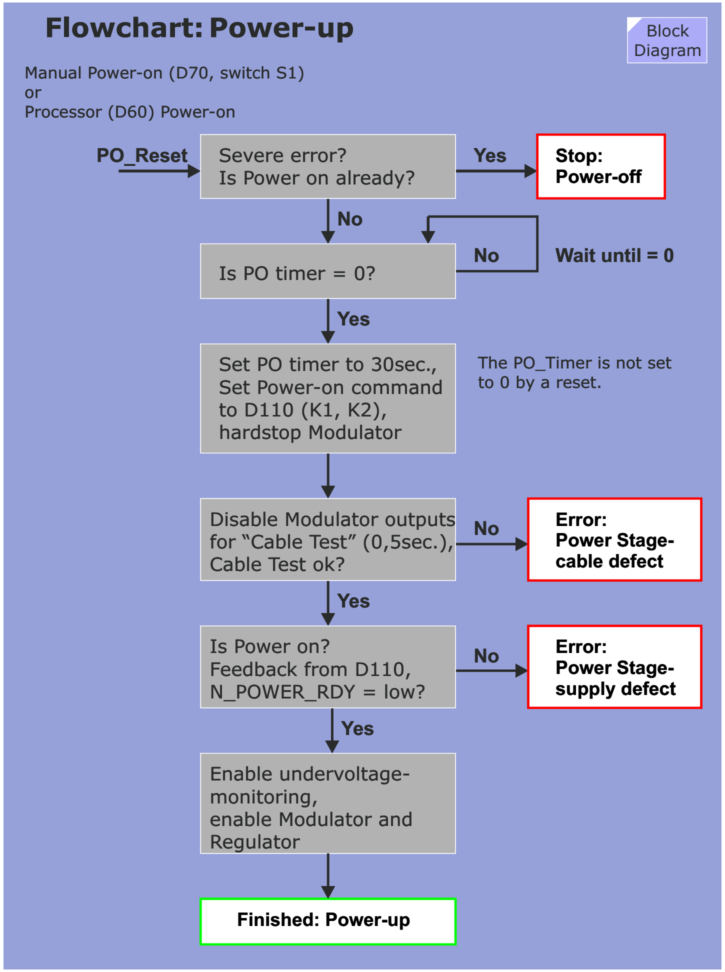
- **Modulator enable**: The modulators are not disabled when the power stage supply voltage is switched off.
- **Synchronization fault**: The fault is handled as a "warning" only.
- **Closed loop error**: The fault is handled as a "warning" only.
- **"Soft" stop**: No modulator "soft" stop in case of low voltage faults at the power stage.
- **Voltage feedback error**: The fault is handled as a "warning" only.
- **Oscillation error**: Regulator may oscillate for a longer period of time (approx. 12 sec. instead of 3 sec.) until the fault is reported.

GPA Power-up

The D40 controls the Power Stage supply switching-on and -off by controlling the power relays at the D110 Power-UP board (see also D110 description). At the beginning of the power-up routine all stored errors are reset, if a fault occurs later on, the D40 will power-off the supply and generate the corresponding error message.

NOTE Power-up can take up to 30 seconds due to internal timer at the D40 Modulator-board.

Figure 140 GPA Power-up Flowchart



Jumpers

Jumper	Position	Description
X6/ X7/ X8	open	not used
X9	1-2	Stimulation Monitor active
X10/ X11	1-2/ 1-2	Slew rate adjusted by D60
X12	open	not used, for PCB test only
X13, X14	1-2	normal operation/ PCB test

Switches

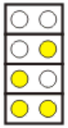
NOTE D40 boards ordered from spare parts stock will have switches S1-S3 set to default settings which, if not properly set, will lead to a "Modulator defect" error! This was done intentionally as this board is used on other systems requiring different switch settings. You must set the correct switch setting before use! Switch and jumper settings are found in the **Diagrams**

LEDs

16 different error codes can be displayed in dual code with help of four error LEDs (V125 - V126). Furthermore, the logic can identify two different fault classes (indicated by LED V124 left/ right = MSB1/ 0):

- common faults for all axes
- axis specific faults for X, Y and Z-axis

The first severe error that is recognized is always displayed by a LED pattern that lights up very bright, following errors are displayed by a darker pattern. Any minor problem is indicated as "warning" only (yellow LED V123/right lights up additionally).

LED	Status	Description
V120 left:	on flashing	all Modulators on all Modulators on, but warning
V120 right	on flashing	Power Stage power supply on Power status is changing
V121 left	on	+5V ok.
V121 right	on	+/-15V ok.
V122 left/ right		max. output voltage 500V max. voltage 1000V max. voltage 1500V (**Q or Z -engine**) max. voltage 2000V (**SQ or DZ-engine**)
V123 left	on	Modulator defect
V123 right:	on	Warning
V124 left/ right		see page 189
V125/ V126		see page 189
V127	on	Service Mode on

NOTE A minor problem is indicated as "warning" only (yellow LED V123/right lights up additionally).

Figure 141 *D40 Front View*

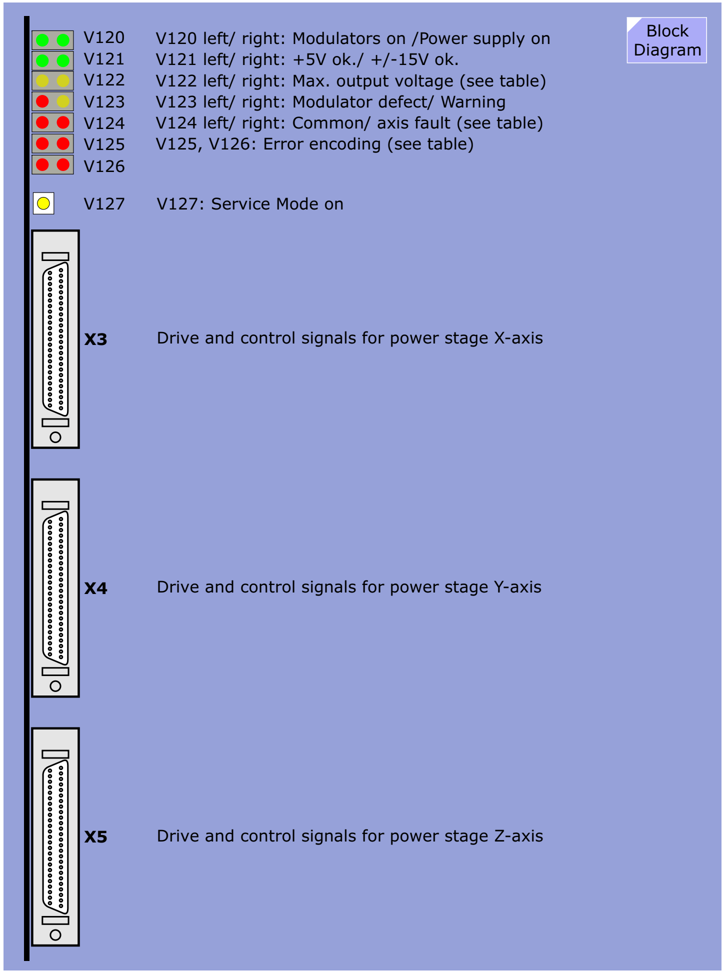


Figure 142 *D40 LED Error Patterns*

Block Diagram

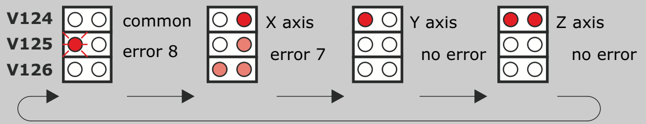
Error	LED V125/126	LED V124	Description
0	LEDs flash ◐◐ ◐◐	common	Regulator Oscillation
		X, Y, Z	Voltage feedback error
1	○○ ○●	common	GPA error, look for other errors
		X, Y, Z	OFF from system (D60)
2	○○ ●○	common	Soft stop from system (D60)
		X, Y, Z	switched off by D70 (S3, S4)
3	○○ ●●	common	Fan-error
		X, Y, Z	Over current (Imax. > limit)
4	○● ○○	common	Control Signal to Power Stage defective, Modulator defective
		X, Y, Z	Duty cycle too high
5	○● ○●	common	Wire to Pow. Stage missing, cable pull protect.
		X, Y, Z	Ohm power loss too high
6	○● ●○	common	switched off by Stimulation Monitor
		X, Y, Z	current value (sensor) error
7	○● ●●	common	Not used. Set jumper D70 X15 Pin A4-B4
		X, Y, Z	Regulation (loop) error
8	●○ ○○	common	GCS or Gradient coil overtemp
		X, Y, Z	Modulator control signal freq. too high
9	●○ ○●	common	Power Stage defect (Power on error, extreme power)
		X, Y, Z	Driver power supply defect
10	●○ ●○	common	GPA air temperature too high: >42°C warning - LED V123R on >47°C error
		X, Y, Z	Power Stage over-temperature (cool water)

Error	LED V125/126	LED V124	Description
11	●○ ●●	common	Modulator off (3-phase PS-supply is off)
		X, Y, Z	Power Stage overvoltage
12	●● ○○	common	3-phase Power Stage supply defect
		X, Y, Z	Power Stage low voltage
13	●● ○●	common	Main Transformer over-temperature
		X, Y, Z	Rectifier over-temperature
14	●● ●○	common	Synchronization error
		X, Y, Z	Output inductor (choke) over-temp.
15	●● ●●	common	Not used. Set D70 jumper X16 A12-B12
		X, Y, Z	Power Stage control cable defect

LED V124 :

○○ common ○● X axis ●○ Y axis ●● Z axis

An example :



V124 indicates a common fault is being displayed and V125,126 show the error number 8 pattern. Also, this LED lights up very bright indicating this error ocurred first.
Then in succession the X, Y and Z axis errors are displayed, whereby only the X axis is displaying an additional error, error number 7. Here the LEDs light up only at half brightness indicating it is a secondary error.

D60 CAN & Service

The CAN & Service board consists of two functional blocks:

- **CAN-Module** (Communication and supervision)
- **Signal multiplexer** (Loop).

The CAN-Module is responsible for the data transfer between the AMC and the GPA. Control data for the GPA is transferred from the AMC and GPA-status information to the AMC.

The signal multiplexer is used to connect signals generated in the GPA to the AMC (PCI_MON board). This link allows the software evaluation of the selected signals for stimulation monitoring and Tune-up and tests.

CAN-Module

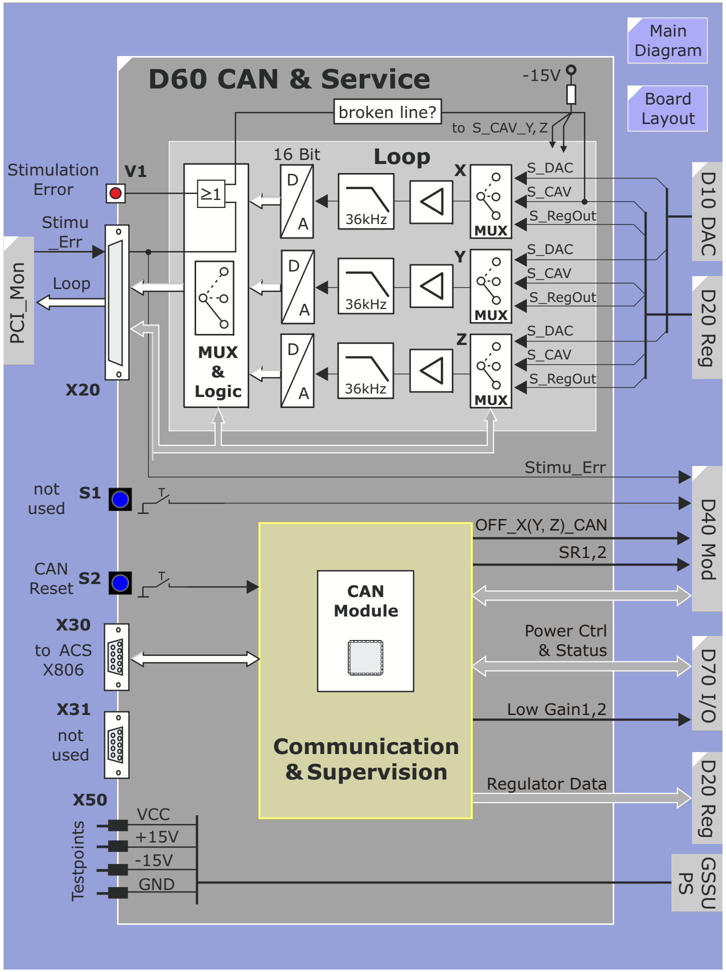
Communication

The firmware (FW) stored in a PROM allows the processor to run a self-test and to communicate and load the application software over the CAN-Bus. The application software (LW) for the processor is stored in an EEPROM. According to this program the processor is able to receive control data from the AMC and transfer status information from the GPA to the AMC.

Reset

The front panel push button S2 is used to reset and re-start (warm start) the Processor.

Figure 143 *D60 CAN & Service*



Signal Multiplexer (Loop)

The signal multiplexer can select 3 analog GSSU signals from each gradient axis via the backplane:

- **Current actual value** S_CAV_X(Y, Z)
- **Nominal value** S_DAC_X(Y, Z)
- **Regulator output** S_REGOUT_X(Y, Z)

Tests and Tune-Up

These signals are converted into digital data and fed to the AMC for software evaluation, e.g. for tests and Tune-up under SESO.

Stimulation Monitoring

During imaging sequences the 3 current actual values **S_CAV**_X(Y, Z) are converted into digital data and fed multiplexed via X20 to the PCI_MON board in the AMC for stimulation monitoring. In case of exceeding critical thresholds, the PCI_MON sets the **Stimu_err** signal and the D60 will "soft stop" the modulator.

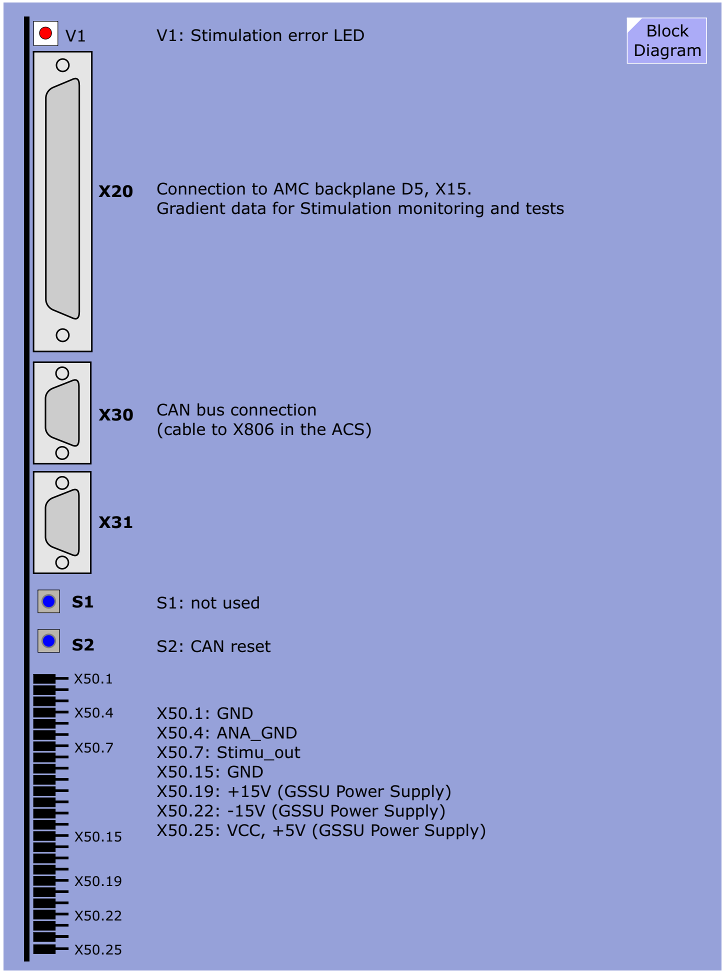
Switches

Switch	Description
S1 (push button)	not used
S2 (push button)	performs reset of the CAN controller

LEDs

V1 (Stimulation error) lights if the critical gradient stimulation values are exceeded.

Figure 144 *D60 Front View*



D70 I/O

Function

The I/O-board is an interface board between the GSSU and the GSSU power supplies but also to the power stage section. Control and monitoring signals are fed via this board to the modulator board D40 and the D60 CAN & Service board.

Power Switching

The D40 Modulator board controls the power switching that can be initiated by the processor D60. For service purposes the GPA can be switched on or off by push buttons **S1** and **S2** at the D70-board. See D110 description for details.

NOTE The Power Stage capacitors normally require approximately 20 minutes to fully discharge after a normal switch-off. This time can be shortened to under 1 minute by enabling the Service Switch **S4 right** on the D70 and turning the power Stage power supply off by using **S2** on the D70 board.

Service Switches

The design engineers have provided several switches for service use. See table below for description on switch functions

GPA Air Temperature Monitoring

An on-board NTC monitors for air over temperature. The AIRTEMP_WARN (>42^{0}C) and AIRTEMP_ERR (>47^{0}C) signals inform the D40 Modulator-board about that problem.

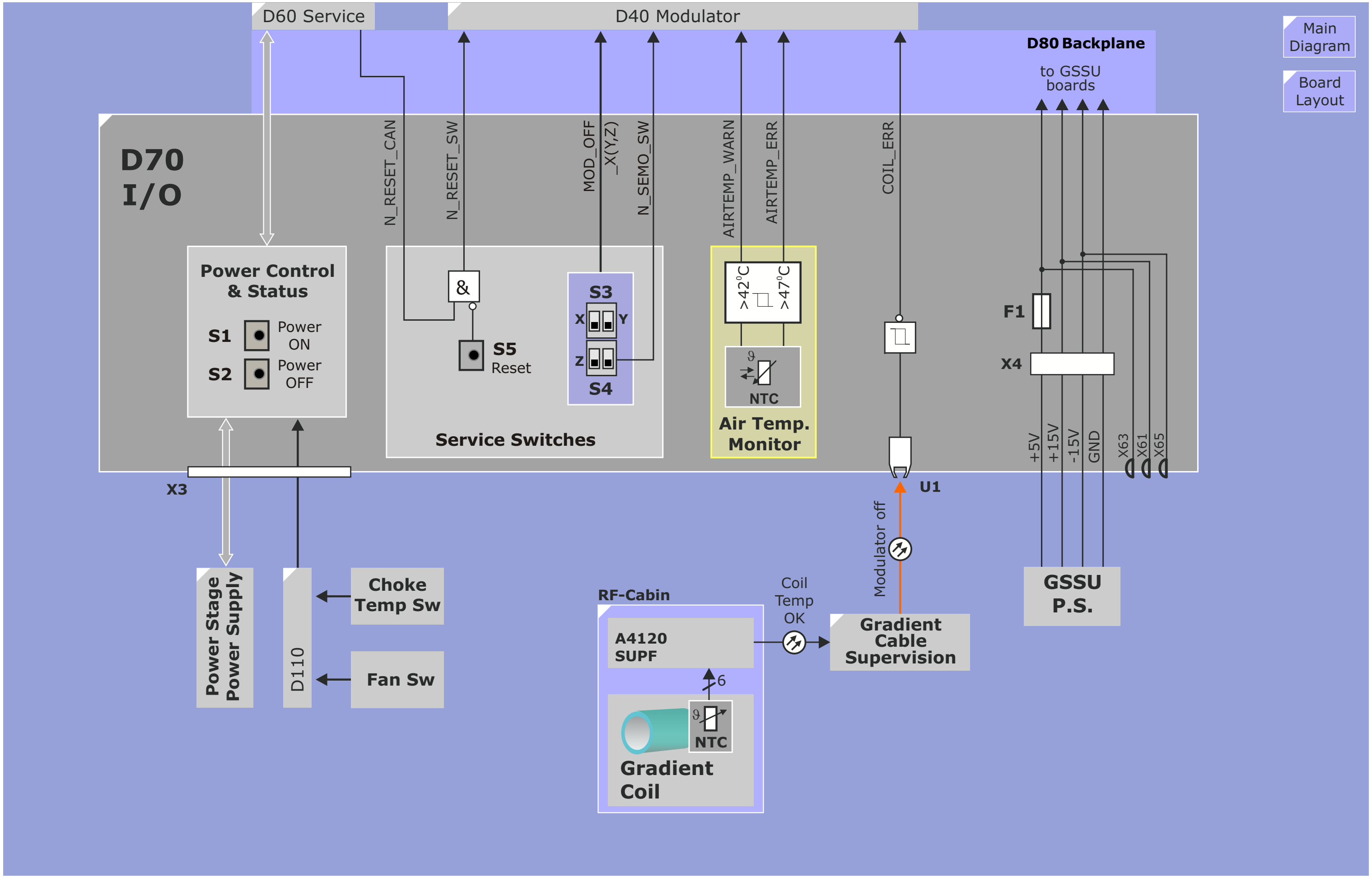
Interface for Gradient Coil Temp Monitoring

The temperature of the gradient coil is measured with six thermal resistors (NTCs) located in the gradient coil and connected via X50 to the monitoring circuit SUPF (Supplied functions, A4120-board) of the Patient Table Control electronics frame. From there, the signal is routed via fibre optic connector U9 to U1 at the D70 I/O-board (no light = gradient coil over temperature = COIL_ERR).

Voltage Supply for the GSSU boards

The +5 V (VCC) and the +/-15 V from the GSSU power supply is fed over connector X4 to the D70. Buffer capacitors for all voltages and a 6.3 A fuse (F1) for the +5 V supply is located there. The buffered voltages are supplied over the backplane to all GSSU boards and can be measured at test points at the front side of the board.

Figure 145 *D70 I/O Overview*



Switches

Switch	Description	Position
S1	Power on switch (mains power)	
S2	Power off switch (mains power)	
S3 left	Modulator X on/off	down/up
S3 right	Modulator Y on/off	down/up
S4 left	Modulator Z on/off	down/up
S4 right	Service mode off/on	down/up
S5	Reset of errors (at D40)	

LEDs

LED V68 (green) on the front side, indicating (AC secondary) LINE_VOLT ok is not used.

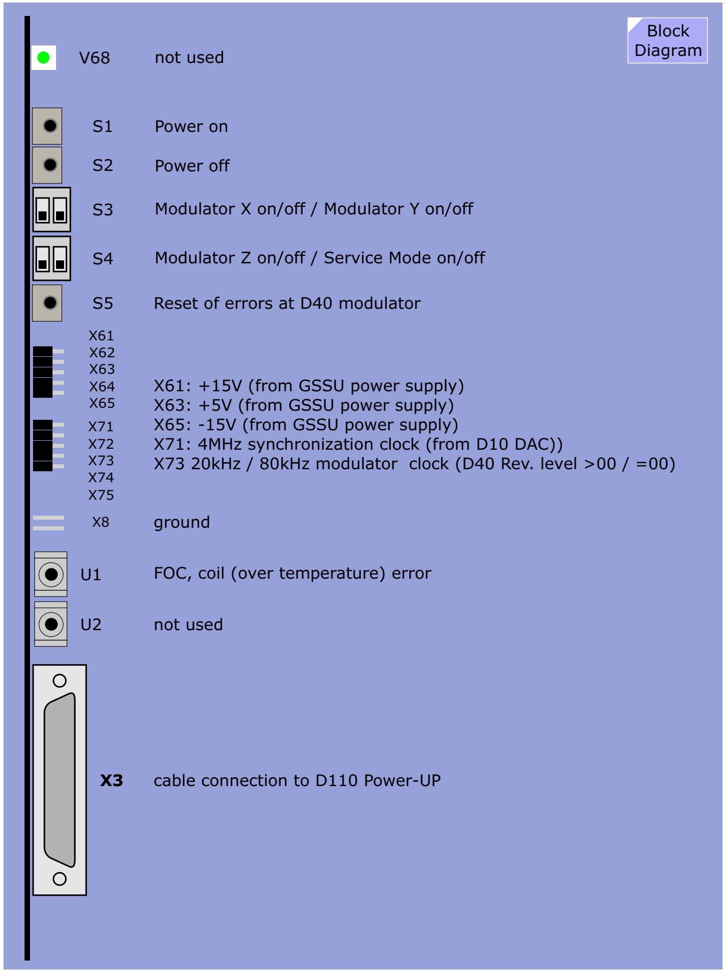
Fuses

There is a 6.3 A fast-blow fuse F1 on board for the +5 V voltage.

Test Points

The +5 V (VCC) and the +/-15 V from the GSSU Power Supply can be measured at test points at front side of the D70 board as well as two important timing signals: 4 MHz sync clock and the 20 kHz/ 80kHz (depending on D40 board revision level) Modulator synchronization clock.

Figure 146 *D70 Front View*



Jumpers

By means of inserting the jumpers X15 and X16 each of the errors passing the D70 board can be jumpered out. In that case the desired error is not monitored anymore!

Jumper	Position	Description
X15	A1-B1	simulates N_Power_Ready
	A2-B2	not used
	A3-B3	bypass POWER_ON_ERR
	A4-B4	not used, but must be inserted to avoid an error
	A5-B5	bypass FAN_ERR
	A9-B9	bypass RC_TEMP_X error
	A10-B10	bypass RC_TEMP_Y error
	A11-B11	bypass RC_TEMP_Z error
	A12-B12	bypass FI_TEMP_X error
	A13-B13	bypass FI_TEMP_Y error
	A14-B14	bypass FI_TEMP_Z error
X16	A1-B1	bypass TRAFO_TEMP error
	A2-B2	simulates LINE_VOLT ok
	A3-B3	not used
	A4-B4	bypass UV_X error
	A5-B5	bypass UV_Y error
	A6-B6	bypass UV_Z error
	A7-B7	bypass OVV_X error
	A8-B8	bypass OVV_Y error
	A9-B9	bypass OVV_Z error
	A10-B10	not used
	A11-B11	bypass COIL_ERR (coil temperature)
	A12-B12	not used, but must be inserted to avoid an error
	A13-B13	not used
	A14-B14	bypass AIRTEMP_WARN error

CAUTION **Although X15 and X16 can be used for advanced troubleshooting, a wrong setting of these jumpers during normal operation may lead to severe hardware damage!**

GSSU Power Supply

Function

The GSSU Power Supply generates three stabilized DC voltages for the GSSU boards, a 17 VDC voltage for the drivers in the power stage modules and a 24 VDC voltage for the relays and fans in the Power Stage Supply section.

CAUTION **The GSSU Power Supply is connected to the mains by circuit breaker F2 directly! Switching-off F1 will not remove power from the GSSU!**

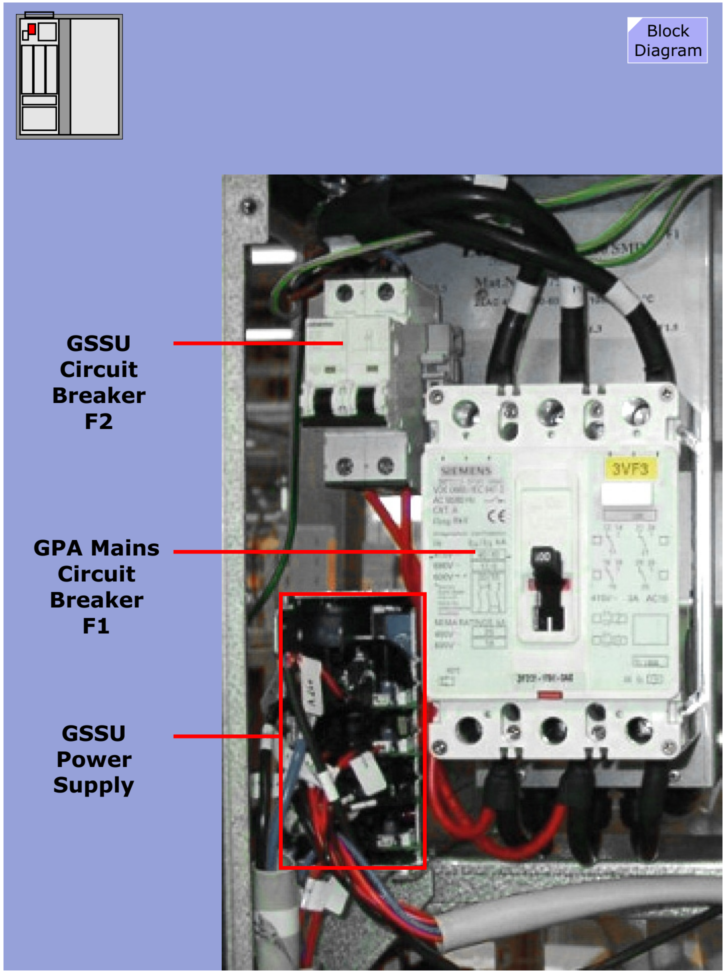
NOTE Voltages are measured with disabled modulators (S3 left/ right and S4 left at D70 set to upward position).

Test Points

All stabilized DC voltages are adjustable by potentiometers on the respective power supply.

Slot #	Voltage	Test point
1	17.0 V ±100 mV (driver supply)	Output connectors, Slot 1
2	5.075 V ±25 mV (GSSU boards)	D70 X63/X8
3	+/-15.05 V ±25 mV (GSSU boards)	D70 X61,X65/X8
4	24.0 V ±500 mV (Power Stage relays and fans)	Output connectors, Slot 4

Figure 147 *GSSU Power Supply*



Power Stage Supply

Function

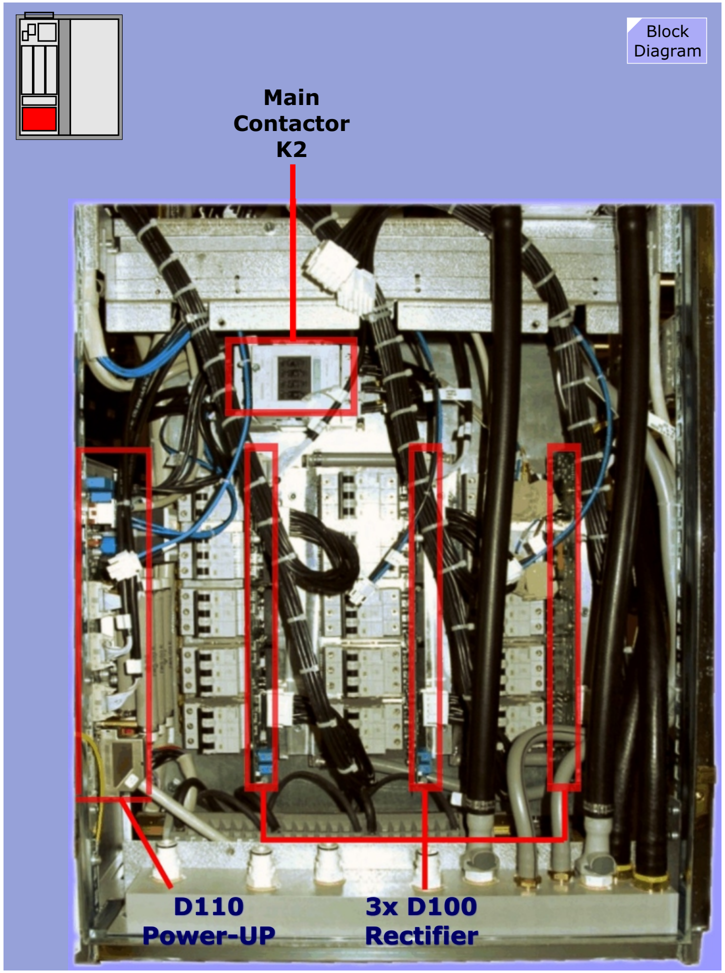
The mains voltage (L1, L2, L3) is taken directly from the customer mains and fed over a line filter and a 100A circuit breaker F1 to T1. The presence of the line voltage is shown by three yellow LEDs (V101, V201, V301) at the D110 Power-UP board.

To avoid extreme current peaks, the mains voltage is switched to transformer T1 via a "soft start unit" (D110 Power-Up). First, relay K1 energizes and connects the current limiting resistors to the transformer, then K2 activates and establishes a direct line connection. The T1 secondary provides fifteen 283 VAC 3-phase outputs for the Power Stage Supply. The AC voltages are fed via fifteen 3-phase 32A circuit breakers to the three D100 Rectifier boards.

After rectification, each D100 provides five 400 VDC outputs for the cascades in the Power Stage.

CAUTION	**To fully disconnect the Gradient System from the line voltage, both circuit breakers F1 and F2 (GSSU power supply) must be switched off!**

Figure 148 *Power Stage Supply*



D100 Rectifier

Function

The following description refers to Figure 149, page 199

Voltage Generation

Each D100 Rectifier board is equipped with five 3-phase rectifiers to rectify the 283 VAC secondary outputs of transformer T1 into five 400 VDC supply voltage outputs for the Power Stages.

Rectifier Temperature Sensor

The rectifiers are actively cooled with water by the scanners Cooling System. A PTC temperature sensor mounted on the rectifier cooling rail is used for monitoring. The PTC output is evaluated by a monitor located on the D110 Power-UP.

AC Voltage Monitoring

The input voltages from transformer T1 are monitored for 283 $V_{eff.}$ ±10%. LED V185 lights to indicate when this voltage is in specification. The monitor output signals Volt_ok1(2, 3) are fed to the D110 additionally. This signal is NOT monitored by software!

DC Voltage Monitoring

The five DC output voltages are monitored for over voltage (>450 VDC) and under voltage (<80 VDC) conditions. The corresponding status signals N_OVV_X(Y, Z) and N_UV_X(Y, Z) are routed via the D70 to the D40 Modulator board for reporting.

LEDs V1017-V1021 light when the voltage level is above 80V.

LEDs

LED	State	Description
V185	green	all secondary AC voltages ok (283 $V_{eff.}$ +/- 10%)
V1017-V1021	yellow	DC voltage present (>80 V)

D110 Power-UP

Function

The following description refers to Figure 149, page 199

The D110 is responsible for the following main functions:

- Power Up Soft Start, Power Off
- Rectifier temperature monitoring
- Signal buffering

Power Up Soft Start

The Power Stages contain a large number of high-capacity buffer capacitors which necessitate a soft start circuit to limit the current while the capacitors charge. The soft start circuit consists of:

- Power Sequencing
- Damping resistors
- Over-current detection

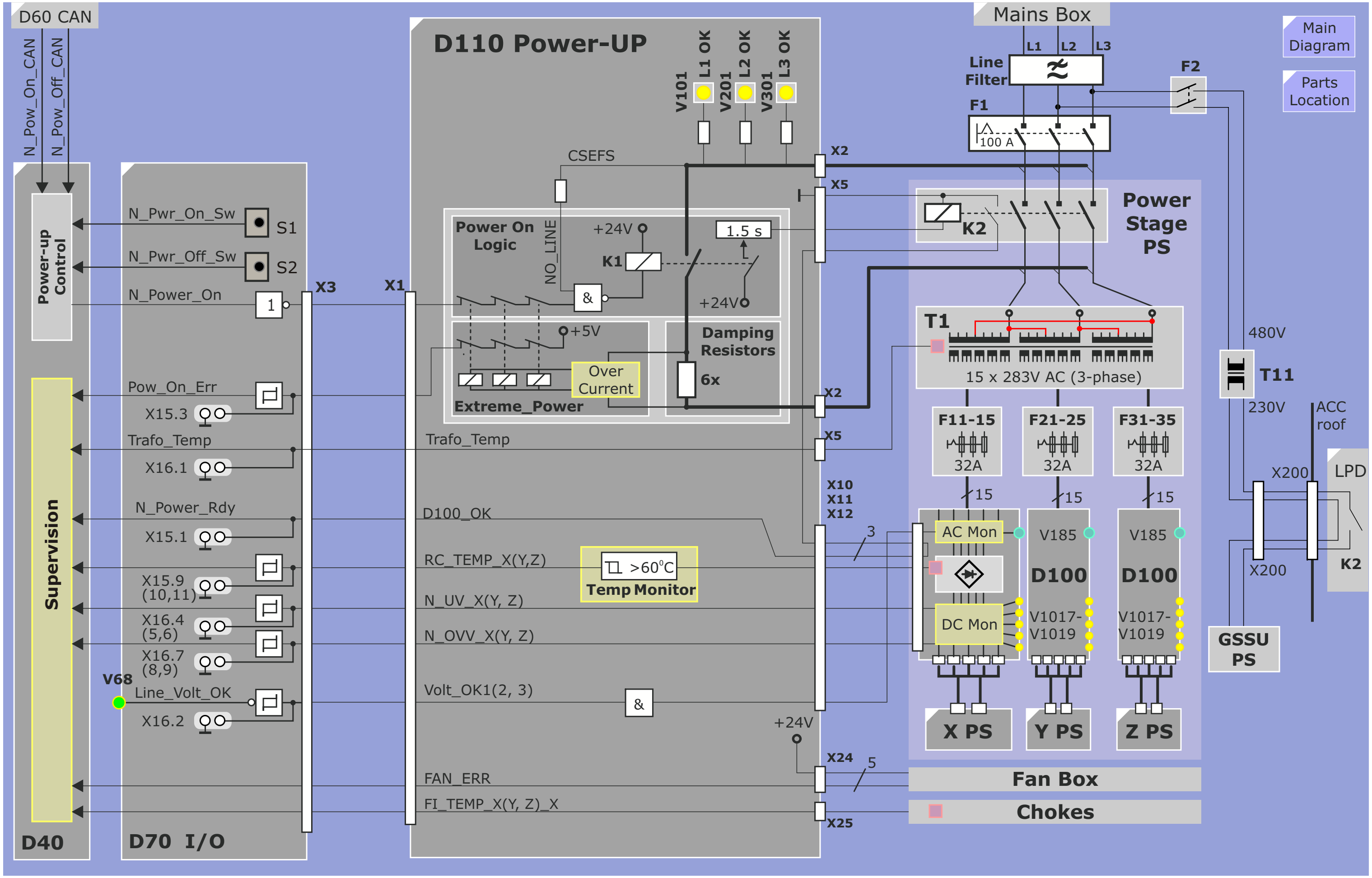
Power Sequencing

The power switching is initiated by the N_POW_ON_CAN signal from the D60 or with push button **S1** on the D70. The D40 first performs a test to check for a "Power Stage cable defect" (see D40 description). If successful, the **N_POWER_ON** signal is set and the start up is initiated.

The N_Power_On signal is fed through three relay contacts and is ANDed with the **CSEFS** (CSE forgot switch) signal, a signal indicating F1 is CLOSED. If **F1 has been switched OFF**, the power up sequence can not be performed. This is to prevent the power up sequencing which ends with the closure of K2. When K2 is closed the soft-start is bypassed! If F1 is turned on after K2 has been closed: BOOOOM!

If F1 is closed the N_Power_On signal activates contactor K1, feeding the mains voltage to the transformer over current limiting resistors. After a delay of 1.5 seconds (and no errors are detected) contactor K2 is enabled to establish a direct connection to the mains supply.

Figure 149 *Power Stage Power Supply*



A help contactor on K2 informs the modulator that the power-up was successful (**N_POWER_RDY**). This signal is also looped over X10, X11, X12 to the three D100 Rectifier boards to assure they are plugged in (D100_OK signal). All modulators and regulators are now enabled and the D40 activates its DC low-voltage monitoring (N_UV_X(Y, Z) signals).

Over-current Detection

If during the soft start the current through the current limiting resistors exceeds limits the respective relay (K100, K200, K300) is activated and interrupts the K1 control voltage. The "EXTREME_POWER" error is generated to the D40 Modulator.

Power Off

In case of an error the GPA can be switched off by the D60 (N_POW_OFF_CAN signal). Push button **S2** on the D70 board can also be used (N_POW_OFF_SW). Both signals are fed to the D40 where a “soft stop” blocks all modulator axis, the Power Stage low-voltage monitoring is disabled and the N_POWER_ON signal is set to high logic status (relay K1 and K2 opens). The modulators are finally switched off by “hard stop” (see D40 description).

Rectifier Temperature Monitoring

Each of the three D100 boards is equipped with monitoring circuitry for the secondary AC-voltages from the main transformer T1.

A PTC at the rectifier cooling rail is used to detect its temperature. A detection logic at the D110 reports the RC_TEMP_X(Y, Z) error (>60^{0}C) to the D40 Modulator (via D70).

Signal Buffering

Several status signals are fed through the D110 to the D70.

Fan Monitoring

A feedback voltage (low=ok) from the five fans in the Power Stage section is used to check the proper function. If one of the signals fails, a FAN_ERR is reported via D70 to the D40 Modulator board.

Transformer Monitoring

The mains transformer is equipped with an over temperature switch. In case the transformer winding temperature exceeds 180^{0}C, the TRAFO_TEMP signal changes to "high-status" and the D110 via D70 informs the D40 Modulator board.

Choke Temperature Monitoring

The chokes in the Output Filter Assy defective blower for the Power Stages or chokes is reported by the FAN_ERR signal. In case of a choke over temperature the FI_TEMPX(Y, Z) is used for error detection (see D110 description)

LEDs

LED	Status	Description
V101	on	line voltage present (phase L1)
V201	on	line voltage present (phase L2)
V301	on	line voltage present (phase L3)

Power Stages

Overview

Each of the three Power Stage modules consists of 5 cascades (H-bridges) each with its own DC400 V supply. The presence of this supply voltage is indicated by five yellow LEDs at each of the three D100 rectifier-boards. Each Power Stage can deliver a maximum output of 650 A and 2000 V. The following components can be found inside:

- **5 water cooled H-bridges** (cascades) with 4 IGBT-switches each
- **5 times 400 VDC capacitor blocks**
- **Integrated driver supply** with galvanically isolated switch mode power supply
- **Integrated opto-transmitter and opto-receiver** for drive- and monitoring-signals

---

NOTE The Power Stage is a Field Replaceable Unit (FRU)!

CAUTION **The Power Stage capacitors require approximately 20 minutes to fully discharge after normal switch-off.**

NOTE This time can be shortened to under 1 minute by enabling the Service Switch **S4 right** on the D70 and turning the power Stage power supply off by using **S2** on the D70 board.

Figure 150 *Power Stage Modules*

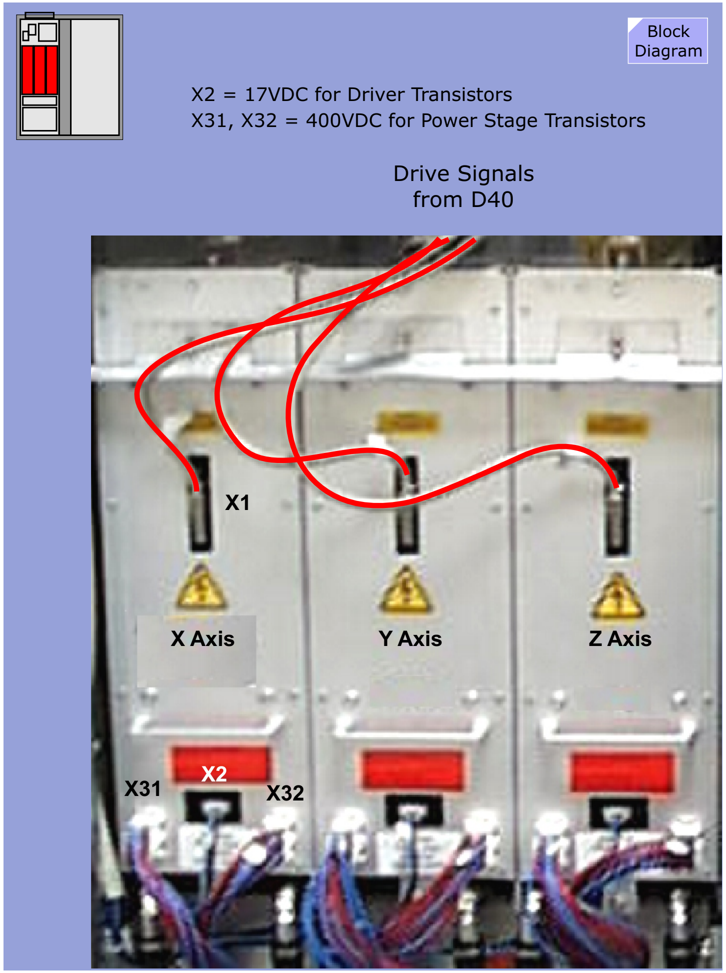
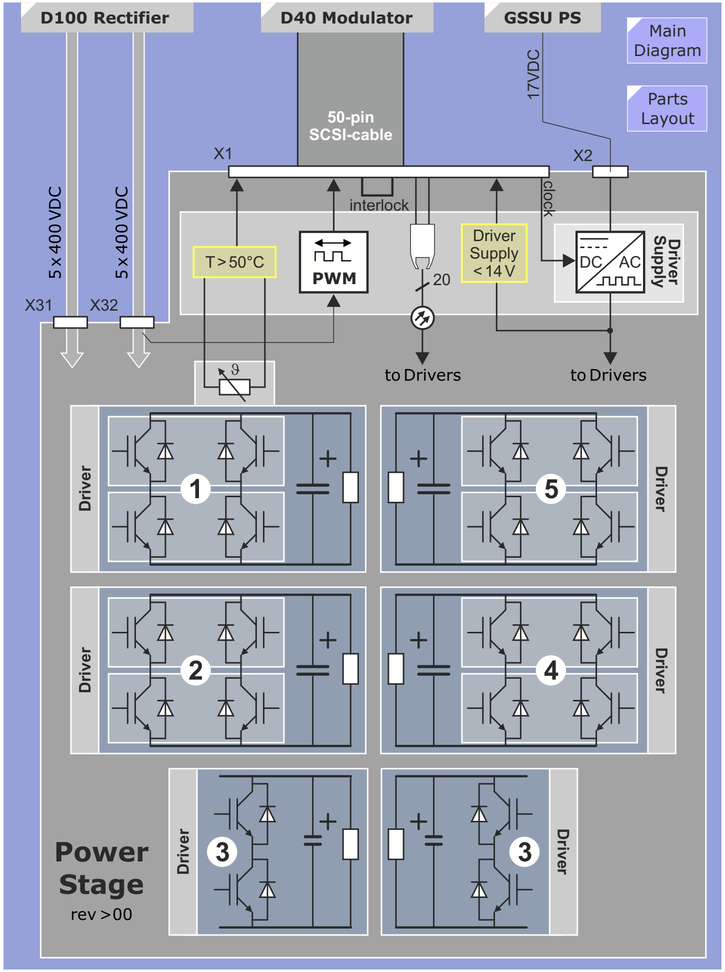


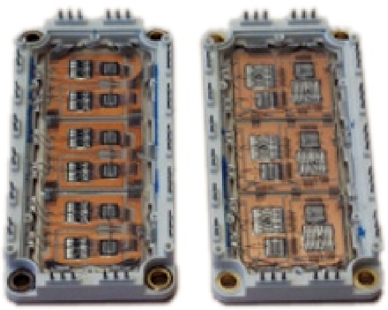
Figure 151 *One Power Stage Module*



Function

Each cascade consists of four switches. The switches are made from 6 parallel connected IGBTs (insulated gate bipolar transistor) with respective free-wheeling diodes anti-parallel.

Figure 152 *Two switches containing 6 IGBTs each*



The switching principle of each cascade is identical to the power stage switching described in the MR-Basics Gradient System documentation. The sequence is:

- **Magnetization / Demagnetization**
  switch 1 and 4 or switch 2 and 3 are activated
- **Upper free-wheeling**
  switch 1 or 3 and the corresponding free-wheeling diode
- **Magnetization / Demagnetization**
- **Lower free-wheeling**
  switch 2 or 4 and the corresponding free-wheeling diode

Output Filter Chokes

Six Output Filter-Chokes are located in a box (Choke-Set). The switching ripple on the gradient current is eliminated by the inductance of two filter-chokes per axis.

Over Temperature Protection

Each choke is protected by a thermal-switch that opens in case of over temperature. A corresponding FI_TEMPX(Y, Z) signal is generated and fed via D110 and D70 to the D40 Modulator-board.

Fan Box

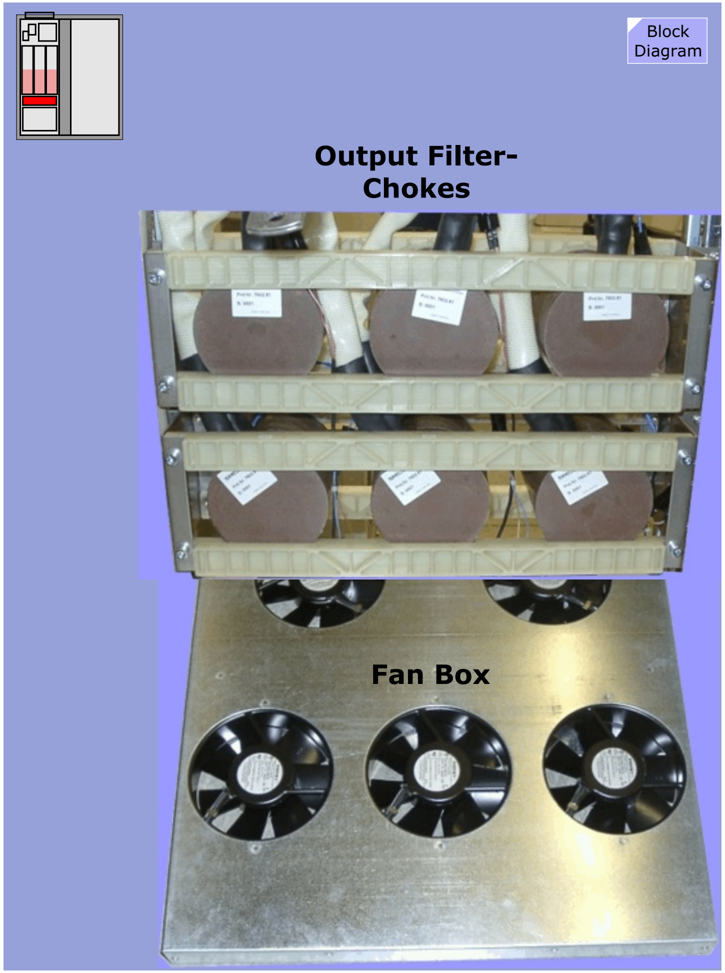
For cooling the Power Stages and Output Filter-chokes, five 24 VDC fans are located in a box underneath.

Fan Monitoring

Each fan is equipped with a built in monitoring circuitry. If one fails, a sum-error (FAN_ERR) is reported via D110 and D70 to the D40.

NOTE The complete Fan Box is a Field Replaceable Unit (FRU)!

Figure 153 *Output Filter-Chokes and Fan Box*



Current Converter Unit (CCU)

Overview

The Current Converter Unit consists of three DANFYSIK current sensors and three LEM current sensors. The sensors are placed in the supply and return sides of the gradient coil, measuring the current both going to and coming back from the coil.

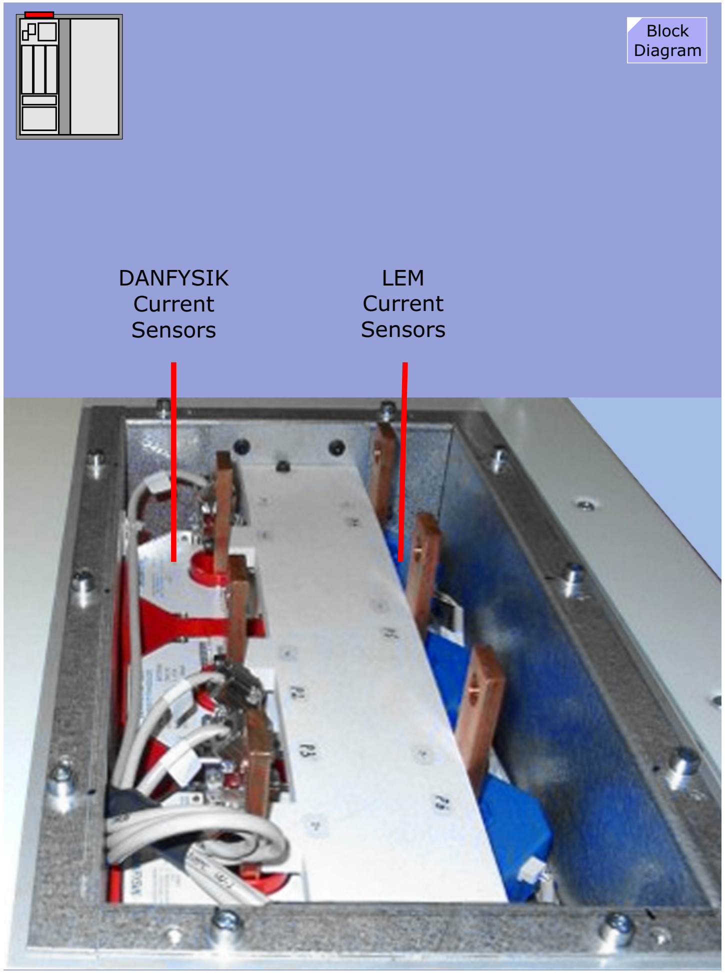
The **DANFYSIK** current sensors are used to supply precise actual current values needed for the regulation.

The **LEM** current sensors are used only for monitoring purposes. Since the output section, including the Final Stages and Gradient Coil and the connecting cables, are floating in respect to ground it is necessary to assure that the current leaving any axis is not returning in through another axis or being shorted to other system components in the event of a short circuit due to a defective coil, cables or filters. Monitoring circuitry on the D20 is responsible for assuring the currents to and from the coil are equal to or less than 32 amps.

In addition, filter capacitors are installed in this unit.

NOTE Each single Current Sensor is a Field Replaceable Unit (FRU)!

Figure 154 *Current Converter Unit (CCU)*



Gradient Cable Supervision

Overview

MAGNETOM Avanto/Espree systems are now equipped or will be retrofitted with an externally mounted **Gradient Cable Supervision (GCS)** unit called the **Siemens VLM** (a smoke detection product line) **Vesda** (product name). The unit incorporates a very sensitive laser-based smoke detection system which can quickly detect particles emitted from overheated connections. The purpose of this unit is to provide continuous monitoring of all critical gradient connections. Poorly fastened gradient cable connections can quickly oxidize and generate extremely high temperatures causing connector/cable damage, and in worst case, fire.

The unit is tied into the MR system so that it can report detected errors and, in worst case, immediately power down the scanner.

Function

Air continuously drawn through a hose system which is mounted over all critical gradient connections and in the ACC cabinet. The air samples are fed through a filter. The filtering of dust and dirt from the air sample is important in order to keep the units optical detector surfaces free from contamination to ensure accurate readings and a long detector life.

Once filtered the air sample is evaluated by a laser detector. If the sample contains small particles (e.g. emitted by overheated gradient connections) the laser beam is scattered which is detected by a highly sensitive optical receiver system.

Figure 155 *Gradient Cable Supervision SIEMENS_VLM*

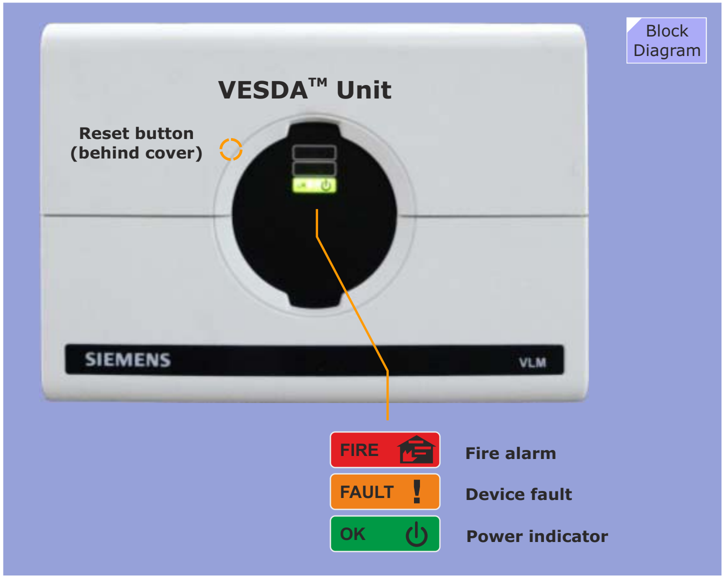
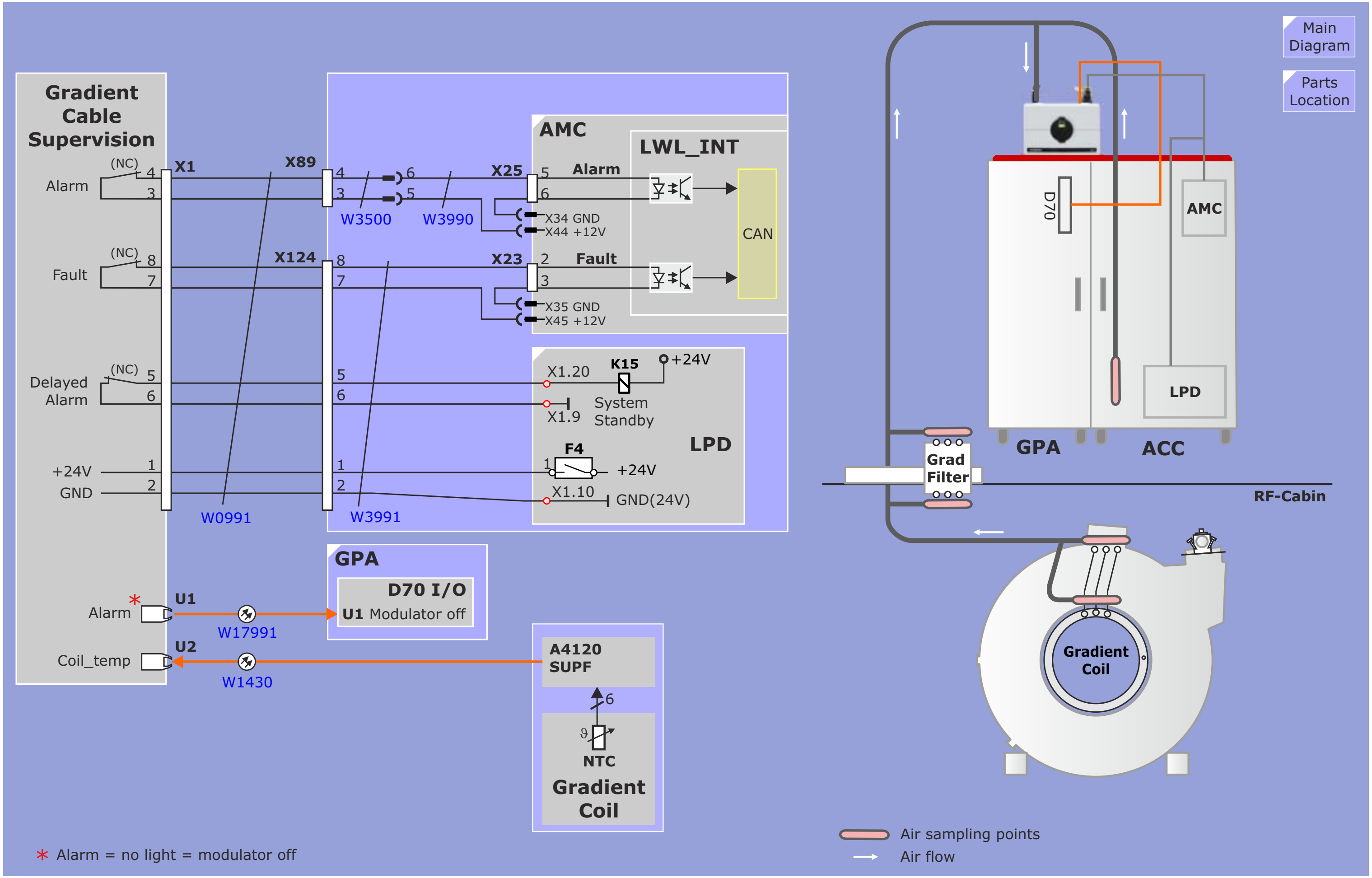


Figure 156 *Gradient Cable Supervision Block Diagram*



Power Supply

The unit is powered with +24 VDC supplied by the 24/36 VDC power supply in the LPD (connector X124 at EPC roof). The supply voltage can be switched with circuit breaker F4.

Device Calibration

Warm-up

After an initial power-up, the yellow FAULT LED lights-up for 5 seconds and the unit runs through a 90 second warm-up cycle.

Reference Airflow Calibration

After initial installation of the unit it will be necessary to **calibrate** the nominal value of the reference air.

NOTE For correct calibration, the sample hose system must be fully attached. Also, close RF-room door to set standard air pressure condition in the RF-cabin.

To start the calibration:

- The unit must be powered-up for more than 90 seconds (= completed warm-up)
- press the units' RESET button under the cover for 10 seconds until all 3 LEDs start flashing
- Release RESET button, all LEDs go off
- LEDs flash again, press RESET once more to confirm setting

The current air flow through the device (which depends on the individual system configuration and hose length) is now **set to 100%**.

Deviations larger than +/-20 % from the 100% nominal air flow (e.g. a blocked or disconnected sample hose) will result in a **device fault**.

Device Fault

Fault LED

In case of a malfunction the units **yellow FAULT LED** will light.

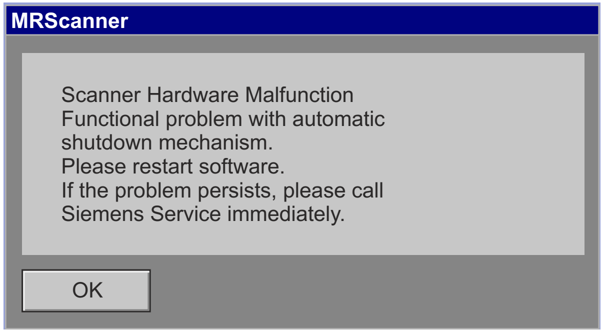
In fault mode, the supervisions' sensitivity is potentially affected, but the operation of the MR scanner is still possible. A constant light indicates a major fault, a flashing LED a minor problem.

The following errors can cause a device fault:

- **Wrong air flow** - more than **+/-20 % deviation** to the calibrated 100% reference air-flow value.
- **Excessive differential pressure** - between RF-cabin and equipment room. A pressure equalization tube must be fitted from the units exhaust back into the RF-cabin

Device Fault pop-up

The customer is informed with a pop-up window.



Device Fault Reset

A Device Fault will be **automatically reset** when the fault condition is not present anymore.

Fire Alarm

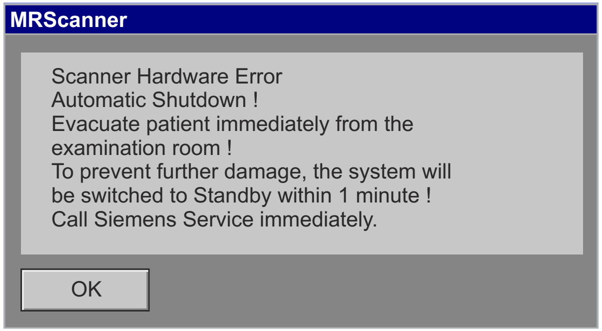
FIRE LED

In case smoke gases are detected within the monitored areas, the SIEMENS_VLM sets the **red FIRE LED**.

Figure 157 *Fire Alarm LED*

Alarm pop-up

The customer is informed about a fire alarm with a pop-up window.



Measurement Abort

The MR system is informed about the critical condition via the connection to the LWL_INT (cable W0991). Consequently, a running measurement is aborted and the modulators of the GPA are blocked (via FOC W17991).

Power Switch-off

After **one minute** the MR-system is **switched to Standby** (via X1 to X124 ACC roof).

Fire Alarm Reset

A Fire Alarm condition is latched by the SIEMENS_VLM to inhibit further system power switch-on attempts.

A CSE can reset the fault by pressing the units' **RESET button**, to be found under the units' cover left to the indicator LEDs.

Jumpers

Jumper	Pins	Setting	Location	Description
Config	2-3	closed	under the units' cover, left of the FOC connector	no alarm = FOC light on alarm = FOC light off

Switches

Switch	Location	Description
RESET	under the units' cover, left of the control LEDs	- Resets latched faults - Set-up button for device calibration

LEDs

LED	ON	FLASHING	Description
OK (green)	Power on	n.a.	Detector is powered up and in normal operation
FAULT (yellow)	Major Fault	Minor Fault	- Calibration of airflow required - Call service
FIRE (red)	Smoke detected	n.a.	- Alarm pop-up generated - GPA modulator will be disabled - MR-scanner will be switched off to standby 1 minute later

Service Procedures

The function of the Gradient Cable Supervision must be checked every 12 months during maintenance.

NOTE For details please refer to the Safety-Related Tests Procedure in the CB-Doc.

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Section

8

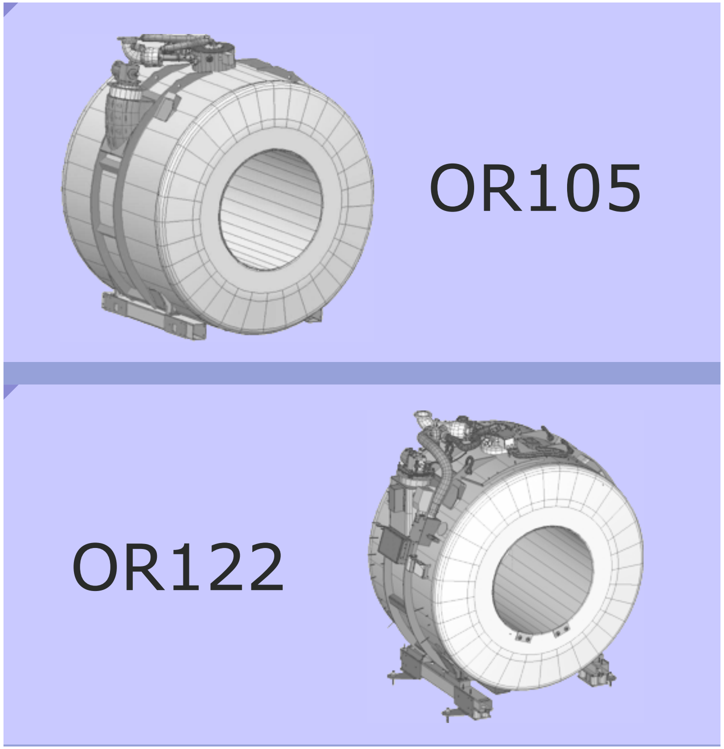
Magnet System

Introduction

Imagine a new super-conducting, short bore, patient-friendly magnet design with large flared opening. AS (Active Shielding), E.I.S. (External Interference Screen) and FCL (Fixed Current Lead) technology for easy siting and installation. A new recondensing refrigeration system to reduce the helium boil-off to zero! Here are the two fascinating Magnet Systems for the MAGNETOM Avanto and Espree:

- **OR105 - 1.5 Tesla magnet for Avanto**: For generation of the main magnetic field B0, maintaining a 500 mm DSV (diameter spherical volume) with superior homogeneity. High patient comfort is realized by a wide open-bore diameter (60 cm including coils) together with a 150 cm short magnet. The magnet has to be passive shimmed during installation to reach the guaranteed homogeneity of the basic field.
- **OR122 - 1.5 Tesla magnet for Espree**: an ultra-short magnet for generation of the main magnetic field B0. Superior patient comfort due to reduction in magnet length (120 cm total length) and increase in open-bore diameter to 70 cm (including coils)! To achieve high homogeneity over the imaging volume of 450 mm x 450 mm x 300 mm (Z), the magnet has to be passive-shimmed during installation. The first series of the OR122 magnet was equipped with two A(2;0) super-conducting shim coils to compensate for the shorter magnet length.

Figure 158 *Avanto, Espree Magnets*



Overview

The Magnet System for the Magnetom Avanto and Espree incorporate the newest features in magnet technology and include the following components:

- **OR105 /OR122 1.5 Tesla Magnet for Avanto / Espree**
  The magnet generates the main magnetic field B_0. The magnet is equipped with shim trays (located in the gradient coil) which are positioned around the perimeter of the bore in the axial direction in which iron plates can be strategically placed to achieve the desired magnetic field homogeneity (passive-shimming). This procedure is performed during the initial installation and must not be repeated unless the magnet experiences a quench. A magnet quench man cause internal shifting of the magnet components causing field deviations that must be re-shimmed.

- **Magnet Monitoring**
  Monitors the magnet and refrigerator system functions and regulates the magnet pressure. Magnet pressure regulation is necessary with a cold head system capable of re-liquefying helium. This is the basis of the 0% helium loss system.

- **Alarm Box**
  Provides the system power on/off/standby buttons, an magnet emergency stop button and LED indicators for the magnet supervision.

- **Advanced High Order Shim** (optional for Avanto)
  For accurate shimming of local imaging volumes an optional 5-channel electrical shim system allows shimming of the second order (the largest) terms. The active shim option consists of a high-precision, high stability shim power supply and the shim coil.

- **Z2 SuperCon Shim** (OR122 only)
  The first series of Espree magnets were equipped with a super-conducting A(2.0) shim coil needed to compensate for its short size. The Z2 shim current is calculated during the passive shim procedure and energized with current via the Advanced High Order Shim power supply. Once energized the coil is persistent (maintains its field).

NOTE	Espree magnets beginning with serial nr. **30555** have been redesigned and no longer have a Z2 supercon shim coil. You're welcome.

- **Magnet Power Supply (MPS 3600)**
  A mobile service tool for energizing the magnet. It is not part of the system delivery.

- **Refrigerator System**
  A SUMITOMO Compressor and Cold Head unit provides cooling of the magnet's thermal shield and liquefaction of the helium gas.

Figure 159 *Avanto Magnet System*

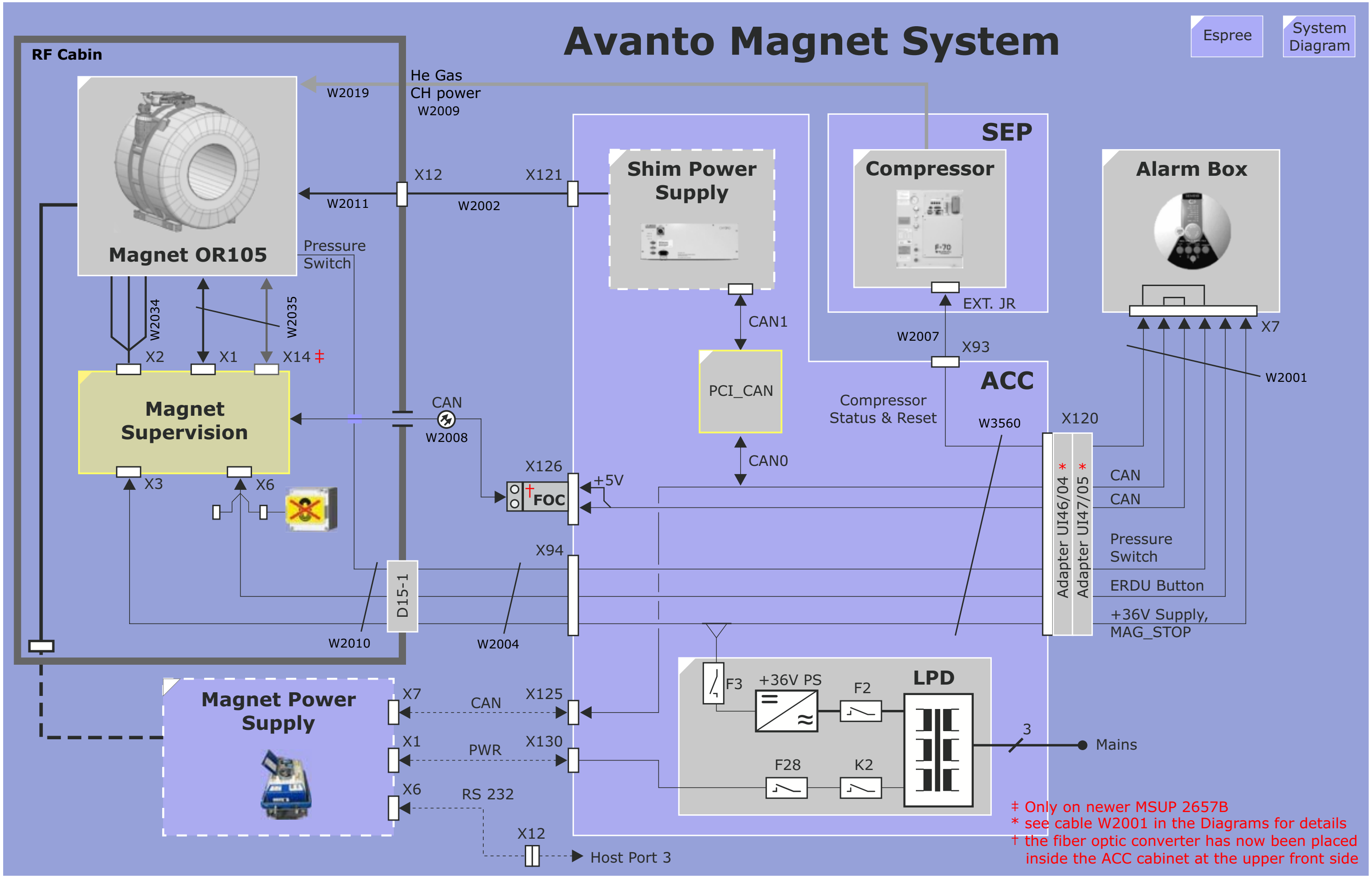
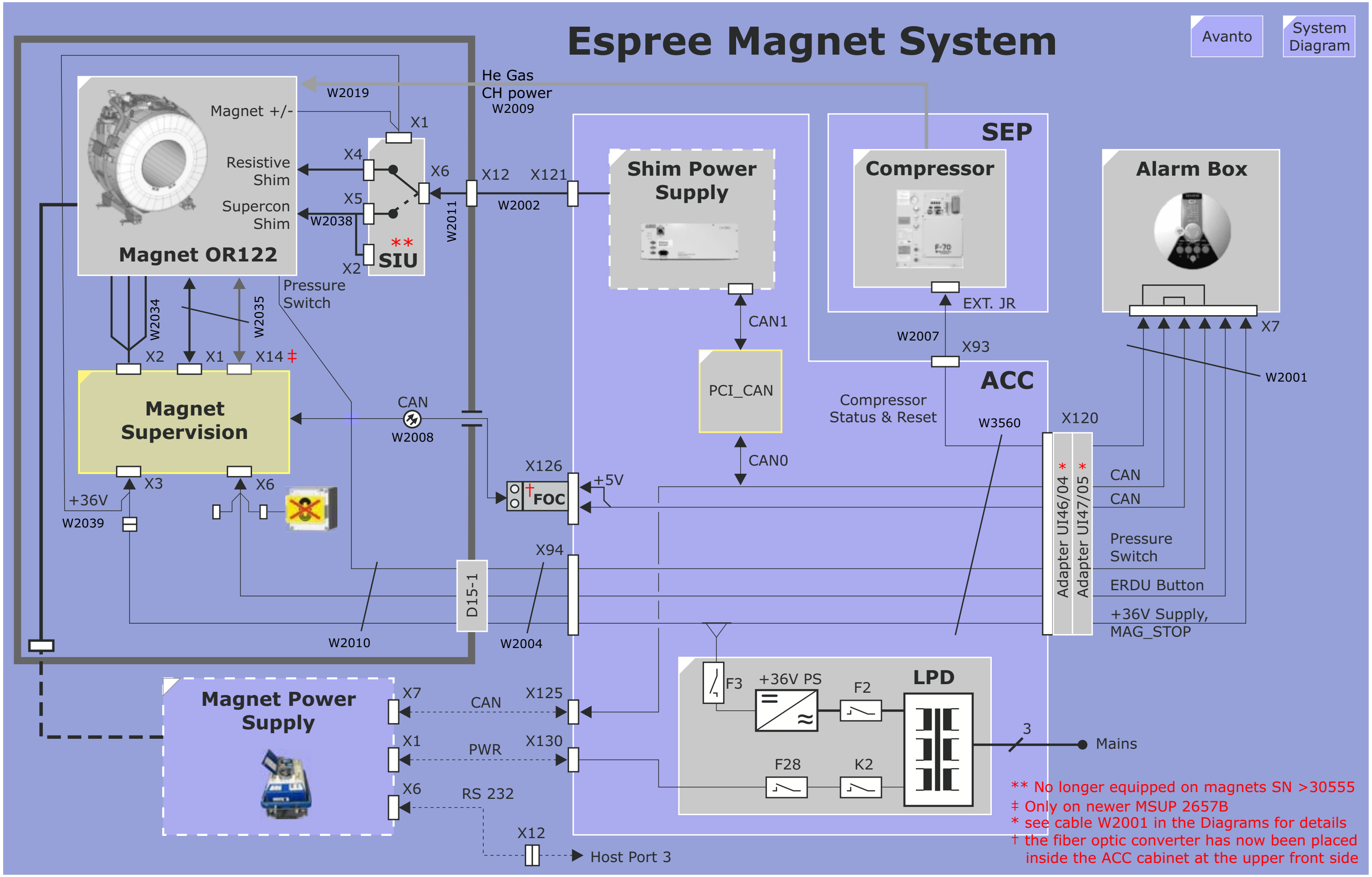


Figure 160 *Espree Magnet System*



OR105 / OR122 Magnet

Overview

The OR105 / OR122 magnets are actively shielded superconductive magnet assemblies sealed into an all welded stainless-steel vessel which is filled with liquid helium. This liquid helium vessel is assembled into an outer steel vessel with pumped-down vacuum to achieve thermal isolation. Inside the vacuum chamber, one aluminium shield reduces the heat radiated to the liquid helium vessel. The shield is cooled by the first stage of a Gifford- McMahon refrigerator manufactured by SUMITOMO. Its second stage recondenses the boiled-off helium gas, hence a zero boil-off system!

The cryogenic and control circuitry access is provided by an integrated turret. A fixed current lead, made of stainless steel allows ramping of the magnet without opening the cryostat.

Specifications

	OR105	OR122
Nominal field strength	1.495 T	1.495T
Max. field decay	< 0.1ppm/h, < 56 kHz/Year	same
0.5 mT fringe field distance	axial (z) 4 m radial (x,y) 2.5 m	axial (z) 4.1 m radial (x,y) 2.5 m
Bare Weight (70% He, without coils and table)	4050 kg	3800
Total Weight (including coils, electronics, table and covers)	5850 kg	5100
Length	1.5 m	1.2 m
Height	2.31 m (2.2 m for Mk II magnets)	2.23 m
Outer Diameter	2.05 m	same
Bore Diameter	0.9/0.6 m	0.9/0.7 m
Imaging Volume	50 cm DSV	45 x 45 x 30 cm
Ramp time to nominal field	45-50 min.	same
Typical Current	512 A	468 A
LHe Volume (100% Helium level)	1400 l	980 l
Minimum Helium level (for operation)	40%	same
He boil off (typical clinical use, depending on sequences and operation times)	0.0 l/h	same
He boil-off per day with Cold Head off (Cold Head vent line open / closed)	3.2% (open) 7.5% (closed)	4.6% (open)

Magnet Coil Components

The OR105 / OR122 magnets are actively shielded magnets consisting of a primary coil having 7 inner coils and 2 active shield coils to reduce the magnetic fringe field.

Switch Heater

A superconductive switch, electrically heated, allows the magnet to be energized and de-energized.

Quench Heaters

In case of emergency (accidents, fire, etc.), the magnetic field has to be de-energized immediately to avoid danger to personnel. Two quench heaters are placed close to the main coil that, when activated. causes the magnet wire to lose superconductivity whereby the current is brought to zero within 20 seconds (Quench). The thermal energy that is released will boil-off a significant amount of the liquid helium.

Quench Protection Diodes

During a quench, up to 6kV can be present within the coil. The quench diodes clamp the voltage to a maximum of around 12V to prevent arc-overs within the wire which would permanently damage the coil.

External Interference Screen (EIS)

The External Interference Screen (EIS) are extra coil windings placed on top of two of the primary coils and both of the Active Shield coils and wired in series. This coil picks up transient B_0 interferences and shields the main field from magnetic field fluctuations caused by moving cars, elevators, power lines, etc.

Over time, the main magnetic field decays (caused by the rest resistance of the coil joints). Hence, a rising current is induced into the EIS, producing a counter-field that deteriorates B_0 field homogeneity. Therefore, the EIS has to be quenched one time per day by the Magnet Supervision Unit (MSUP) timer logic.

Resetting the EIS during a scan would result in image artefacts, thus it is programmed to be performed at 2:00 am.

Z2 SuperCon Shim Coil (Espree OR122 <30555 only)

Due to the shortness of the Espree magnet a large A2.0 shim requirement is necessary. The amount of iron that would be necessary to shim this large term would not fit in the shim trays. Instead, the OR122 is equipped with a super-conducting Z2 shim coil that needs to be energized prior to passive shimming (see description of SuperCon Shim).

Figure 161 *Magnet Electrical Diagram*

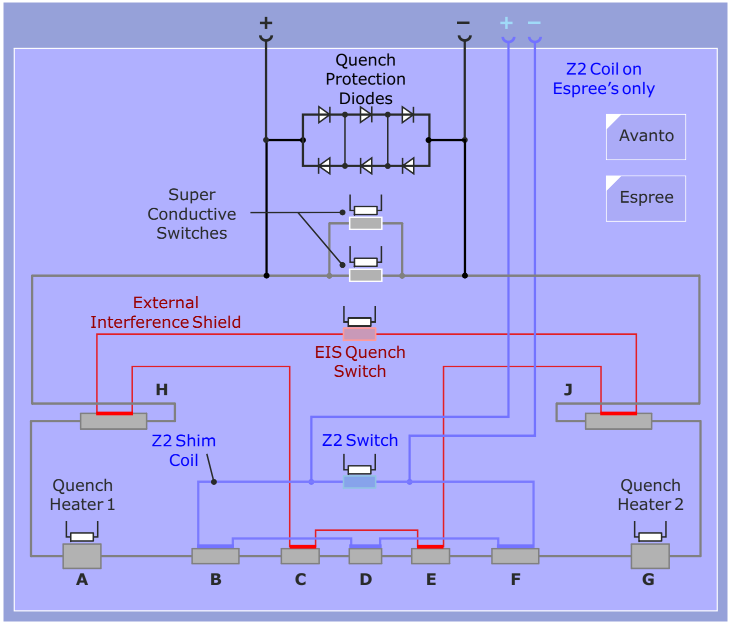


Figure 162 OR105 Cross Sectional Diagram

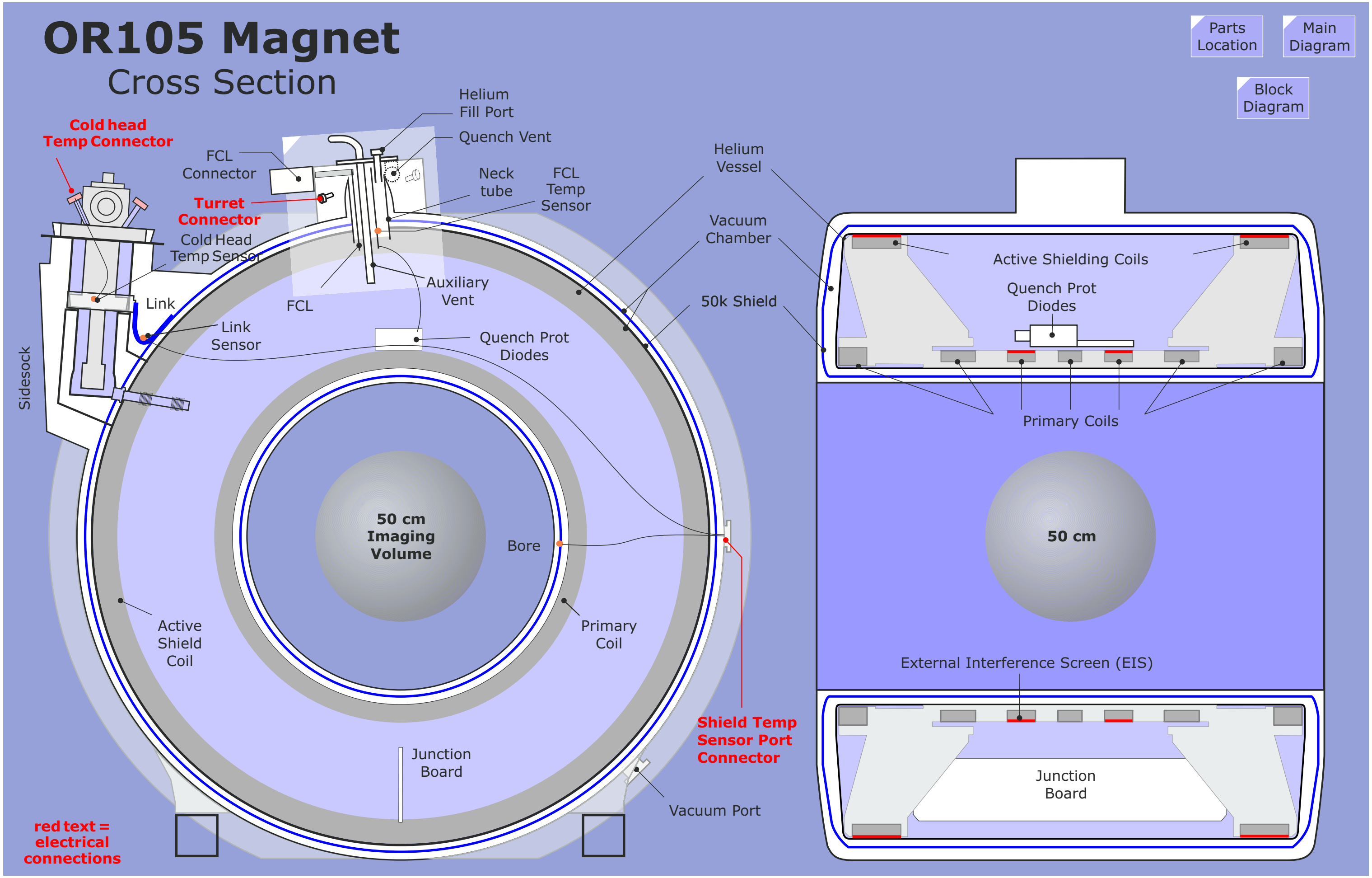
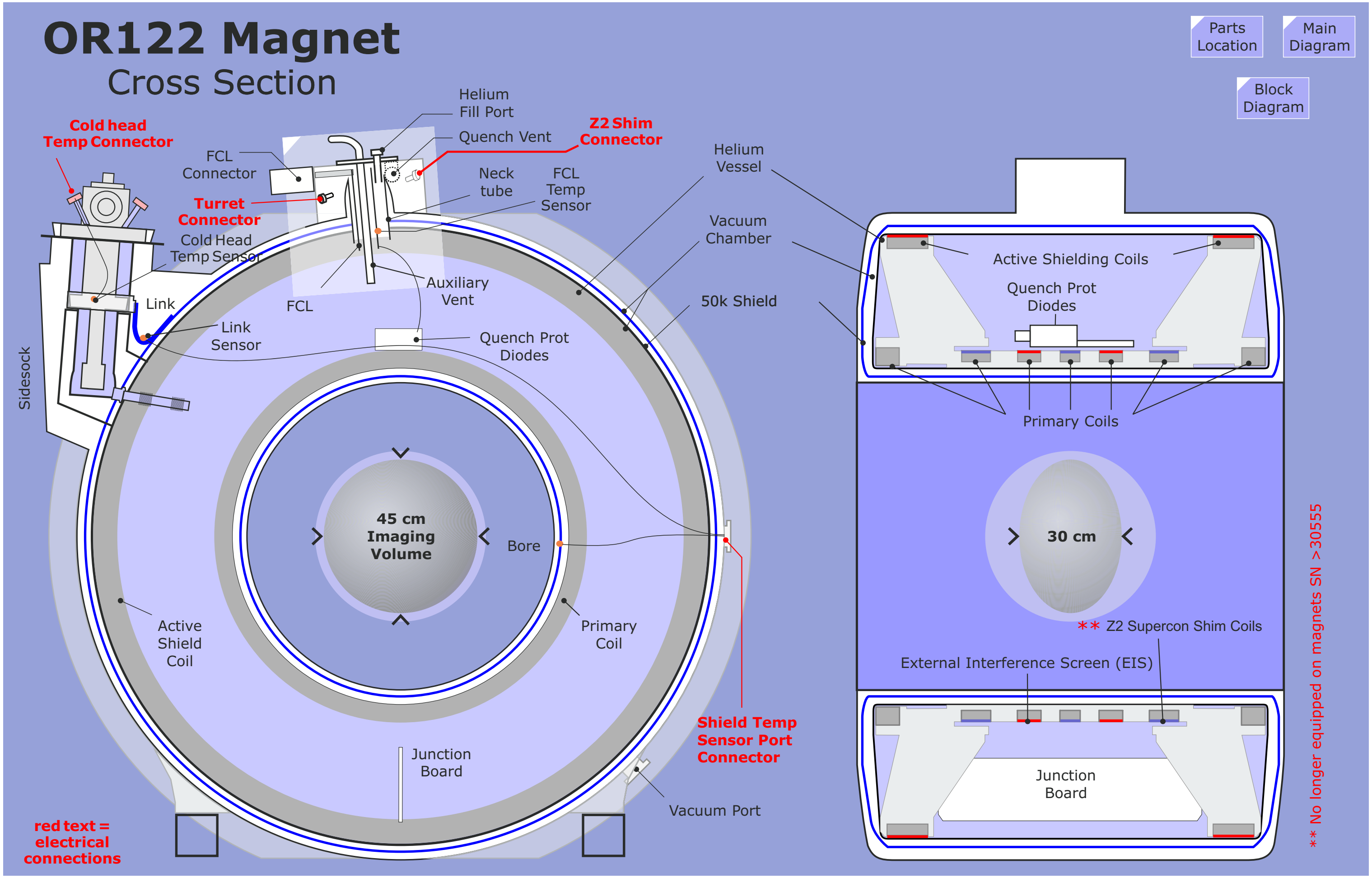


Figure 163 *OR122 Cross Sectional Diagram*



Service Turret

General

The Service Turret is placed at the top of the magnet. It contains:

- Venting system
- Entry port for Helium Fill Syphon
- Fixed Current Leads (FCL) for ramping
- Electrical Interface to the Magnet Supervision (MSUP)
- Electrical Interface to SuperCon Shim (Espree OR122 only)

Venting System

Vent Valve (1)

A 16-psia (a = absolute pressure) vent valve is placed parallel to the Quench valve through which gas can vent when internal pressures exceed 16 psia.

Depressurization Valve (2)

A hand-operated bypass valve placed in parallel to the Vent Valve to allow de-pressurization of the helium vessel.

Cold Head Vent Line (3)

This line is used to allow boil-off gases to pass through the cold head assembly during transportation or then when the compressor will not be in operation for extended periods of time (e.g. long parts delivery time). These magnets typically loose around 7% per day without the compressor. This can be reduced to around 3% with this vent line. During transportation the hand-operated valve is opened to allow boil-off gases to pass through the cold head assembly, thus reducing the heat induced into the helium vessel. As soon as the compressor in brought into operation, the valve must be closed.

OVC Vent (Outer Vacuum Chamber)(4)

The OVC is fit with a pressure relief port (called a drop-off plate) to vent out helium gas in the event helium were to escape into the vacuum chamber. To prevent this gas from entering the examination room this vent is connected to the quench exhaust via the vacuum vent line over a 0.4 bar (5.8 psig) burst disk.

Auxiliary Vent Line (5)

This is a new feature. This vent line extends well below the neck tube assuring that, in the event the service turret is blocked by ice (possible if the quench burst disk is damaged during a quench and air has entered into the magnet), the gasses in the magnet can still escape. Without an alternative path for the gasses to escape, the magnet is, in effect, a ticking time-bomb.

A 1.8-bar (26-psig) stainless steel burst disk is in-line to this vent line and under normal circumstances, the burst disk will not break during a quench.

Quench Valve (6)

The quench valve is realized as a spring-loaded clap valve which opens at 6.3 psig (g = gauged: pressure difference against atmosphere). The spring valve has in addition a graphite burst disk rated at 26-psig which will burst if the spring valve should not open.

Pressure Line (7)

A pressure line from the magnet venting feeds a pressure sensor for measuring the magnet’s internal pressure. The sensor output is fed to the MSUP for pressure regulation. and a pressure switch. See Pressure regulation for a detailed explanation.

NOTE	After a quench the valves of the venting system must be checked for integrity. Please refer to the Troubleshooting Guide "Post Quench" procedure.

Figure 164 *Avanto Magnet OR105 Venting System*

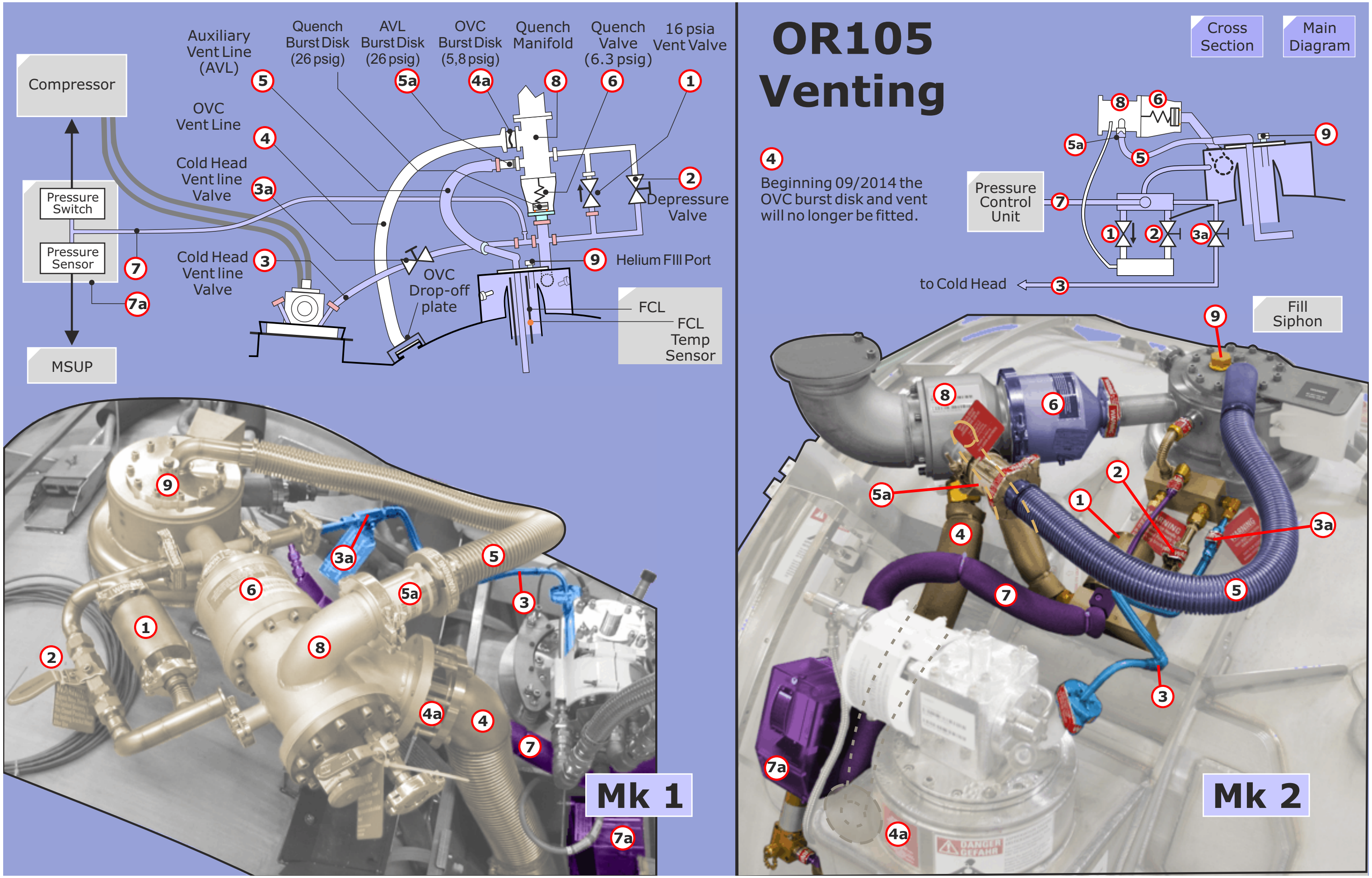
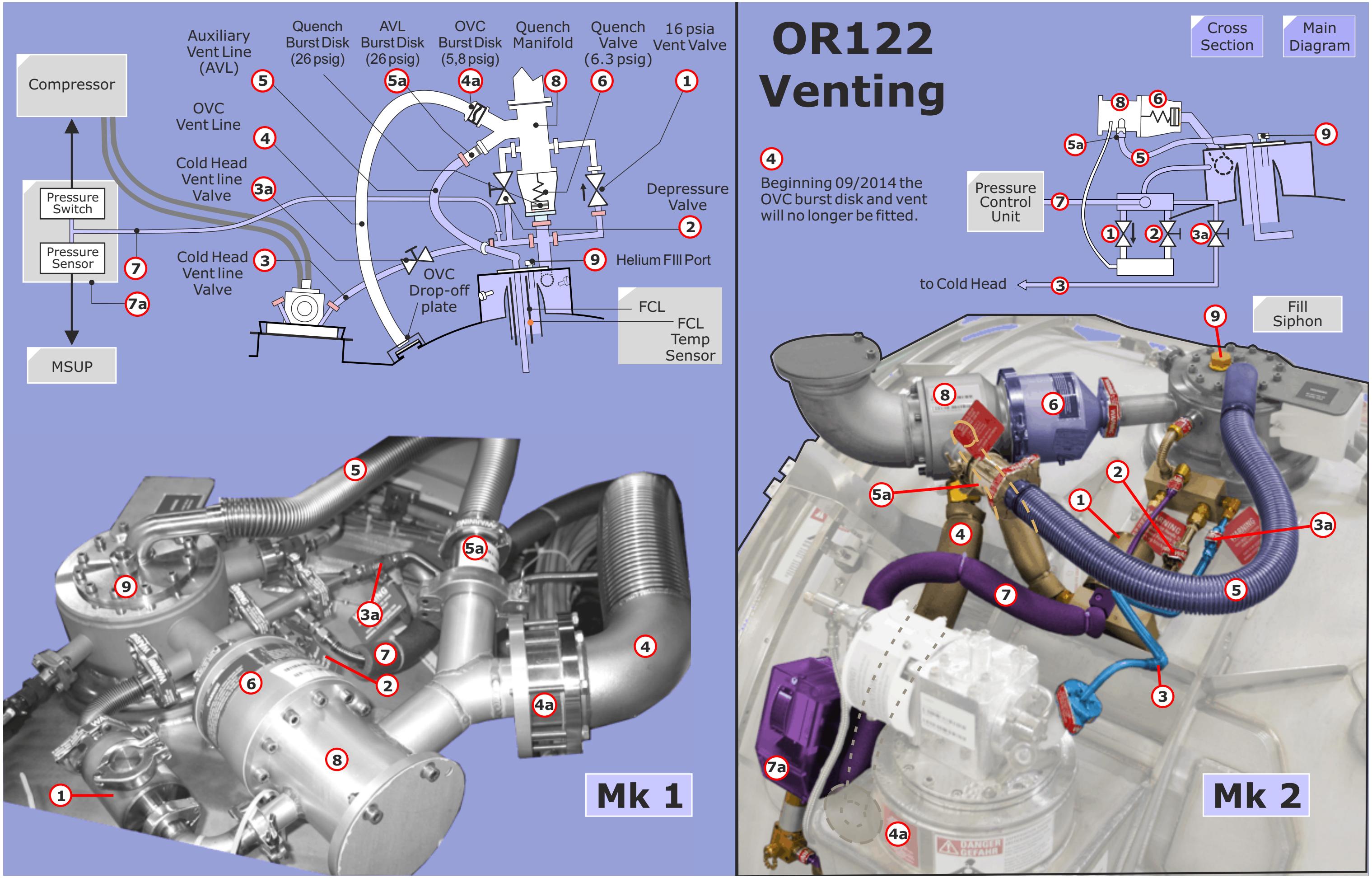


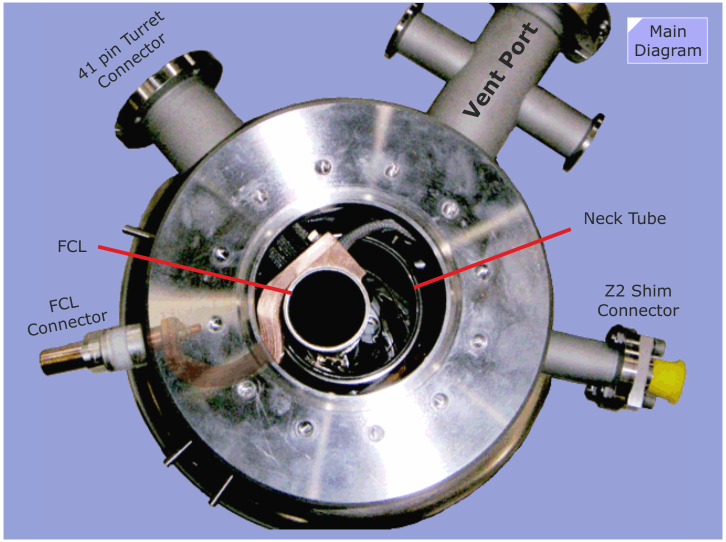
Figure 165 *Schematic of Magnet Venting System*



Fixed Current Lead

The magnet is energized over a Fixed Current Lead (FCL) located on the Service Turret. There is 1 copper connector (positive) attached through the side of the turret via a gas tight ceramic interface. The negative connector is attached to the cryostat shell. No longer the need to insert those unsightly HDL probes! The ramp cables are permanently connected and routed to the RF Filter Panel.

Figure 166 *Fixed Current Lead*



Pressure Control Unit

The Pressure Control Unit contains:

- Analog linear gauge
- Electrical pressure transducer that is monitored by the Magnet Supervision (MSUP)
- Electrical low-pressure switch to control the compressor.

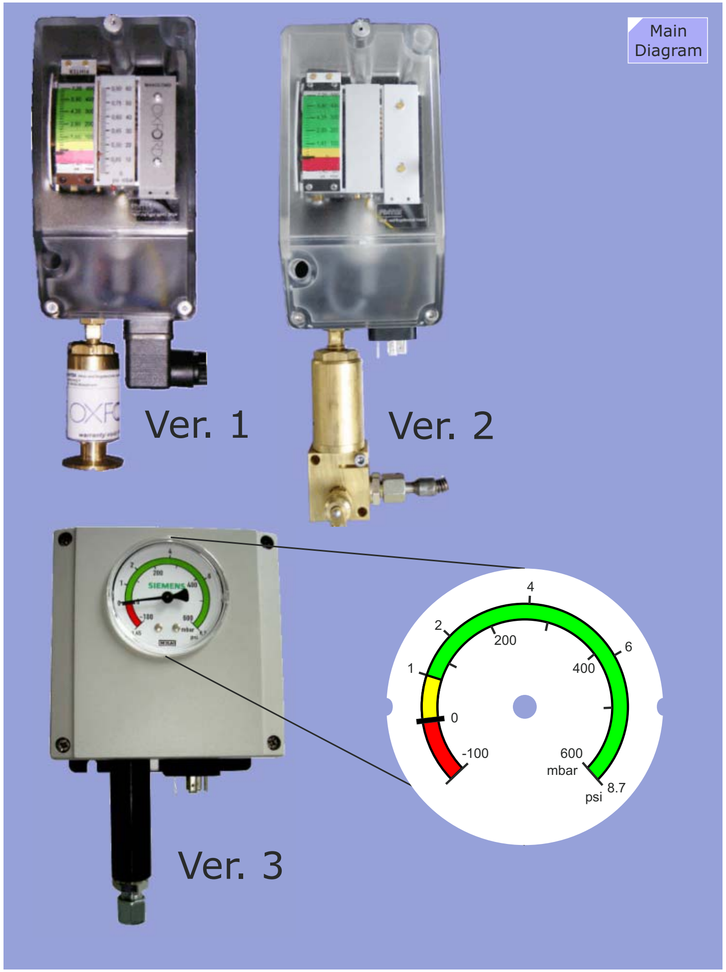
All connections are on the bottom of the unit. The brass connector also incorporates an over-pressure device to protect the unit. The pressure switch is calibrated at the factory and should not be tampered with. The pressure transducer does not require calibration.

Pressure control of the helium vessel is managed by the MSUP (see description on page 230).

In the event that the pressure drops to within 0.2 psi above atmospheric pressure (0.2 psig), the pressure switch will open and turn off the compressor via direct signal cable connection. This measure is taken to prevent air from entering the magnet

NOTE The pressure reading on the analog linear gauge will fluctuate with atmospheric pressure changes!

Figure 167 *Pressure Control Unit*

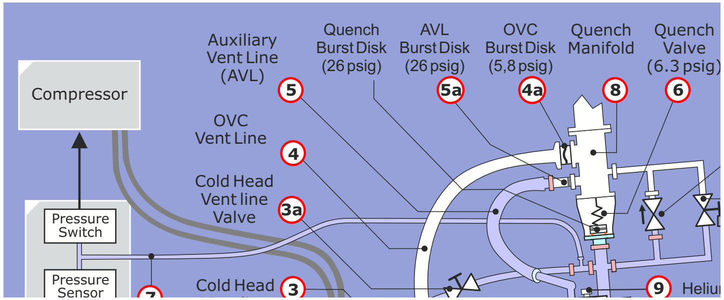


Magnet Supervision (MSUP)

There are 2 versions of the MSUP:

- **K2256** (old Oxford designation 2657A and 2657B)
- **K2306** (for all factory-assembled systems installed with VB19 SP2 (02/2013) onwards and systems factory-assembled and with the Dot option)

Figure 168 *MSUP Versions*



There are also 2 versions of the K2256 MSUP, Version A was without a LVQD function, this was implemented in the K2256B version.

NOTE The **K2306** version is **NOT** described in this document.
Please refer to the **Aera/Skyra Functional Description**.

Magnet Supervision (MSUP) K2256

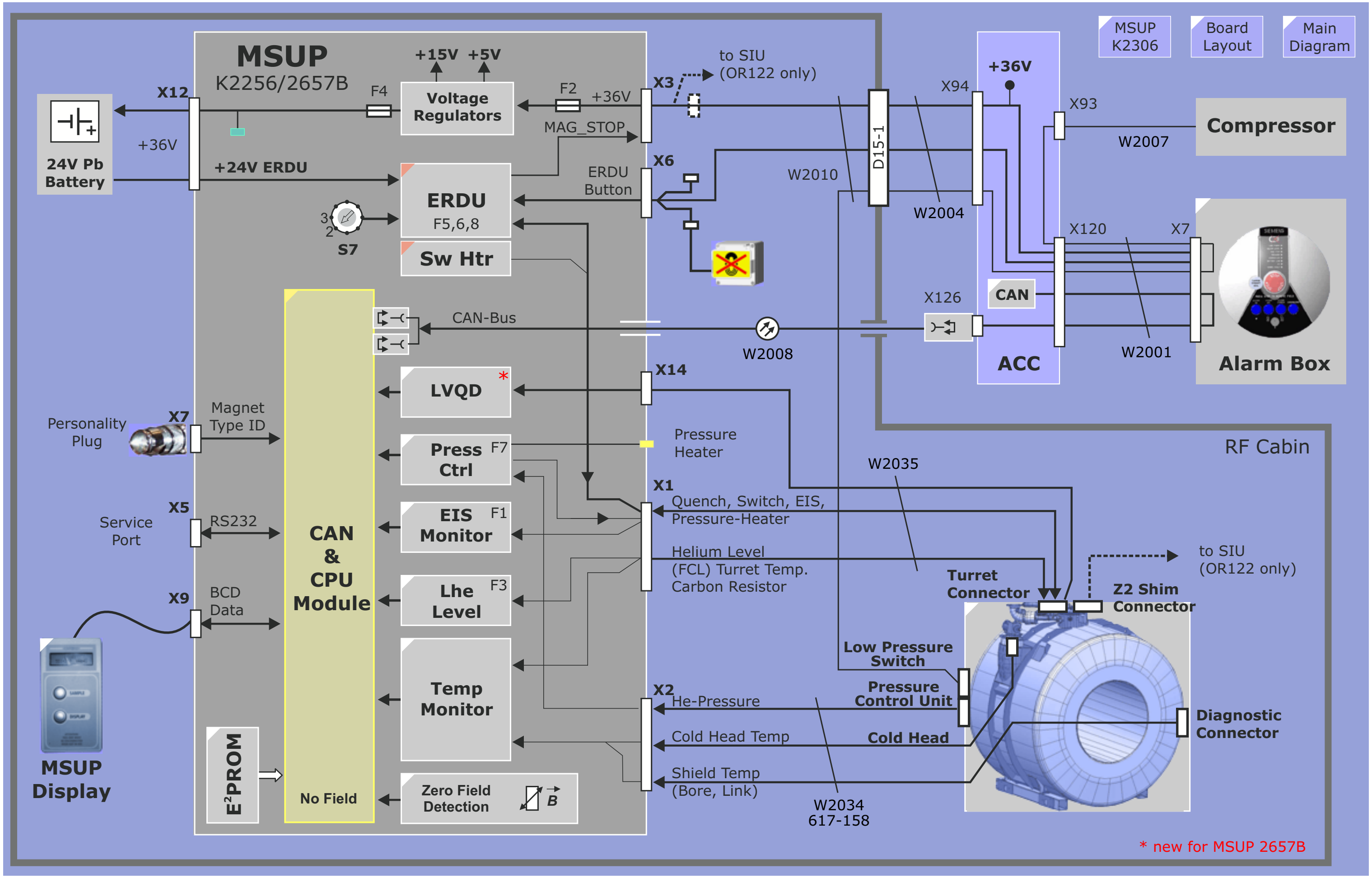
The Magnet Supervision unit supervises and controls magnet functions constantly during normal operation as well as during emergency ramp down. The MSUP supplies the following functions:

- CPU and CAN Module
- Emergency Run Down Unit
- Switch/quench Heater Control
- Helium Level Monitoring
- EIS Control and Monitoring
- Magnet Pressure Regulation
- Magnet Temperature Monitoring
- Zero Field Detection

The MSUP is located at the right magnet side (when facing the magnet from the patient table end). Its operating voltage of 36 VDC is supplied from the ACC and indicated by the green POWER ON LED. A yellow LED indicates up if the Magnet pressure heater is activated.

A 24 V rechargeable battery is implemented to backup the ERDU function. It also provides power to enable sensor readings like LHe-level, to be manually triggered and viewed on the hand held MSUP Display. The battery has to be replaced every two years during preventive maintenance.

Figure 169 *Magnet Supervision Unit K2256*



CAN and CPU Module

RS232 Serial Interface

A laptop can be connected to the serial port (X5). Using HyperTerminal the MSUP log file can be read out (command: **ve**) if needed for analysis or for HSC support. Communication parameters are:

- 9600 Baud, 8 bit, 1 start bit, no parity, Flow Control = None
- File, properties, settings tab, emulation = VT100.

After pressing "Esc" and typing "R" at the Service PC, the communication link is enabled.

NOTE When in sleep-mode the serial comms port of the MSUP is not active. To wake the MSUP up, press "any" button on the Patient Table Control Panel.

Sleep Mode

When a measurement is started the MSUP is put into "sleep mode". In this mode only essential functions are active:

- ERDU circuit
- Pressure regulation circuit, if the magnet pressure drops below 15.0 psia ("hardware control" mode)
- Zero field detection
- Battery-charging circuit

The MSUP will exit from "sleep mode" into "normal mode" when:

- CAN bus activity
- ERDU button pressed
- System off pressed
- Zero field detected (quench)
- Magnet pressure < 14.75 psia

Battery Backup Mode

When a power failure occurs the MSUP will go into the 24 V battery backup mode and the following functions will not work:

- Pressure Heater
- EIS reset

The ERDU, Temp monitoring and helium level monitoring will work, but must be performed manually with the Hand display.

NOTE When the MSUP operates on BATTERY power only, Helium level readings below 45% can be inaccurate.

Internal Self Test

During power up, the processor initializes all MSUP components, performs a self test and checks the +5 V, +15 V and +36 V supply voltages. Additionally some reference voltages are checked to verify the proper function of the multiplexer and ADC circuit for the analogue sensors (e.g. LHe-level measurement).

Magnet Type Identification

The last self test step extracts the Magnet Recognition code from the Personality Plug that is connected to X7 of the MSUP. That information is used to set up a connected Magnet Power Supply accordingly.

Supervisory Test Cycle

The MSUP can perform a Supervisory Test cycle to start a new measurement of:

- Battery test (only if +36 V MSUP supply voltage is present)
- Helium level
- EIS reset

The Test cycle is completed within 30 seconds. It can be started by either:

- Pressing the "SAMPLE" button at the MSUP Display
- CAN-bus commands
- Internal timer - sampling time is set up in SeSo under "Magnet & Cooling / Initialization", normally for 02:00 am

EEPROM

The MSUP EEPROM is used for three purposes:

Storage of Status Entries

256 of the last status entries are stored with time and date stamp.

Recorded Events

The following events are stored with time and date stamp:

- ERDU button pressed or released
- Zero field detection
- Compressor start time and status
- Compressor stop time and status
- last recorded Helium level
- last recorded shield temperatures
- last recorded magnet pressures

Storage of User Configured MSUP Parameters

User configured MSUP parameters stored in the MSUP EEPROM:

- He propagation **pulse height** and **pulse width**
- He **sample pulse** height
- He **level warning** point
- He **0%** and **100%** calibration values
- Magnet **ramp current**
- Supervisory **test time**

Each of the parameters is communicated to SESO via CAN. Validity of the above data is checked permanently by checksum calculation. If a deviation is found, the processor tries to load the internal default parameter table for the recognized magnet type.

MSUP Error Logging

Errors and events occurring when the Host is not available (i.e., system is off or Host is out to lunch) are stored internally in the EEPROM. When the scanner is turned on or rebooted the MSUP updates the log file on the Host: c:\medcom\log\msuphistory.log. This log file is also updated via SeSo / Magnet & Cooling / magnet status.

Emergency Run Down Unit (ERDU)

ERDU Buttons and Monitoring

When an ERDU button is pressed the MSUP energizes the quench and switch heaters which will cause the magnet to lose superconductivity and as a result its magnetic field. The magnetic field will decay in less than 20 seconds.

Monitoring

Each ERDU button has a resistor built in parallel to the switch which is used by the button monitor to detect when a button is missing or activated. **S7** is used to configure the monitor and will be set to the number of connected buttons. There is one on the Alarm Box and at least one in the exam room for a minimum of two buttons. A third button can be installed in the exam room if it has a second door (buttons are placed next to a door).

If a button is missing (pulled or broken cable) or if a button is activated the MSUP will generate a fault message and the red **MAG STOP** LED on the Alarm Box will light. This event is also recorded by the MSUP and will be saved to one of its report files.

Quench Heater Monitoring

The quench heater (and switch heater) resistances are continually measured by applying a small constant current to the heaters and measuring the voltage drop. If a resistance value is found to be outside specification a fault message will be generated and the **MAG STOP** LED on the Alarm Box will light.

ERDU Battery

An external MSUP battery backs-up the ERDU function for 25 days after power failure (assuming one LHe measurement per day and battery was fully charged by the MSUP). The battery voltage can be displayed at the MSUP Display.

ERDU Battery Test

The condition of the ERDU battery is tested when the MSUP starts a Supervisory Test Cycle (e.g. via timer control at night). The MSUP supply voltage (+36 VDC) must be present for that test. A load resistor is connected across the battery and a comparator checks that the battery voltage is within the specified limits. If the battery voltage is less than +23.25 V, a **warning message** is generated although scanning is still possible. If the battery voltage is less than +23 V, an **alarm message** is generated and all scanning is blocked. The red **MAG STOP LED** lights up (in either case) on the alarm box.

Switch Heater Control

The switch heater of the magnet is controlled by the MSUP. When the Magnet Power Supply is connected to the system, it can energize the switch via CAN-bus commands. Like the quench heaters, the switch heater circuitry is permanently monitored for broken or shorted lines. In case of a fault, a unique error message will be sent upstairs to the Host and the MAG STOP LED on the Alarm Box will light.

Parameter	Specification
Switch heater sensor alarm	80>Ohm>200
Quench heater 1 alarm	10>Ohm>30
Quench heater 2 alarm	10>Ohm>30
Maximum SWHTR ON time when MPS is active	10 min.

Helium Level Monitoring

The magnet's helium level is measured with the help of two independent probes. Each probe is constructed out of a single strand of superconducting niobium-tin wire. This wire is heated and its resistance measured, indicating the length of wire not immersed in liquid. Of course, the wire resistances at 0 and 100% helium levels must be known by the supervisory electronics.

The MSUP requires the LHE probe resistances and, depending on software version, other values that are entered into the SeSo Magnet&Cooling / Initialization mask. The magnet-specific values are found in the SMT Factory Acceptance document.

NOTE Helium level readings below 45% can be inaccurate when the MSUP operates on BATTERY power only.

Display of last sampled LHe-level

The LHe filling-level of the Magnet can be seen at:

- syngo MR, System/Control
- Service Software (SESO), Magnet & Cooling Status
- MSUP Display

LHe-level Sampling

A new sampling of the LHe-level can be started:

- Automatically one time per day by internal MSUP timer (sample time setup in SESO, Magnet & Cooling Initialization)
- Manually by calling SESO, Magnet & Cooling Status
- Manually at the MSUP Display

Calibration of LHe-level meters

The two LHe-level meters have to be calibrated in software. The calibration data (e.g. probe resistance values for 0% and 100%) from the SMT Factory Acceptance document have to be entered under SESO, Magnet & Cooling Initialization.

A warning level of 50% (possible range 40-75%) for LHe-level has to be adjusted in SESO, Magnet & Cooling Alarm Settings. If the level falls below that threshold, a warning message is generated and reported to syngo MR.

The Alarm threshold is fixed to 40%, if the level falls below that value, the red "Helium Level" LED at the Alarm Box lights up and the alarm buzzer is switched on.

Monitoring Specifications

Parameter	Specification
He propagation pulse height	0.4 A
He propagation pulse width	25 ms
He sample pulse height	0.25 A
He sample pulse width	10000 ms
Number of daily samples per day	1
He level alarm set	40%
He level alarm clear	50%
He level warn set	50%
He level warn clear	70%

External Interference Screen (EIS)

To shield the magnet from outside electro-magnetic interferences, the magnet is equipped with extra super-conductive windings placed on top of several of the magnet coils (see Figure 162). The windings are tied together to form one single entity and is called the External Interference Screen (EIS). Any outside magnetic influences are absorbed by this winding thus shielding the magnet to prevent field deviations during the scanning. The currents induced in the EIS by the external interferences, as well as the current being induced in the EIS by the normal daily decaying of the main magnetic field must be discharged (quenched) regularly each day to prevent a deterioration of the B_0-field homogeneity. The MSUP quenches the EIS automatically by applying a voltage to EIS quench-heater for 15 seconds. The time of the quench is set in the SeSo, normally at 02:00am, in order to avoid image quality problems.

A manual EIS reset can be performed with help of the MSUP Display (e.g. during shimming). If you were to forget to turn it back off, no problem, the MSUP will switch off the EIS heater automatically after 60 minutes to avoid excessive helium boil-off.

Monitoring

The presence of the EIS reset output current is checked by the MSUP circuitry. In case of a fault, (e.g. broken cable) a warning message is generated and the yellow "EIS" LED at the Alarm Box lights up.

EIS Monitoring Specifications

Parameter	Specification
Maximum EIS ON time SWHTR TON ERDU operated	60 min.

Magnet Pressure Regulation

With a recondensing Cold Head system, a pressure regulation is required to prevent an under-pressure (= subatmospheric) condition within the magnet which could cause air to ingress and freeze in the magnet vessel. The magnet pressure is regulated by the MSUP which gets the actual (absolute) pressure value from the Pressure Control Unit. When the actual pressure value has fallen below the specified nominal value, the MSUP activates a pressure heater to boil off helium. By this means, a constant, regulated magnet pressure can be achieved.

The pressure regulation system can operate at 4 different modes:

- **Normal Mode**
  The magnet pressure is regulated at 15.3 psia
- **Hardware Control Mode**
  A fault condition, the MSUP tries to regulate at 15.1 psia
- **Manual Mode**
  For service, to pressurize the magnet. The pressure heater is activated continuously
- **Safety Mode**
  The magnet is almost fully depressurized, the He-compressor is turned-off by a safety switch to avoid under-pressure

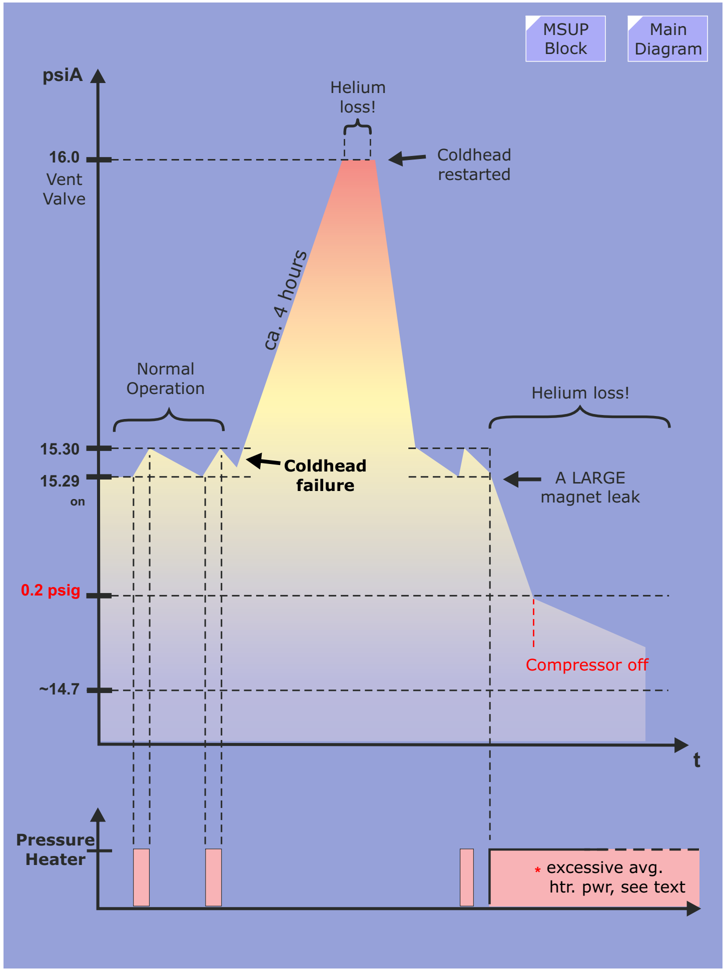
Normal Mode

During normal magnet operation, the MSUP tries to regulate a constant magnet pressure around **15.3 psia**. When the pressure has fallen to 15.29 psia, the MSUP activates the pressure heater to boil off helium. When the pressure has risen to 15.30 psia, the heater is turned off.

Hardware Control Mode

In a service or fault condition (e.g. a leak), when the MSUP requires >1 W average heater power over a 4 hour period, the MSUP will switch into "hardware control mode". In this mode the MSUP reduces its regulation set-point to 15.1 psia and the wattage limit is ignored. On older software the limit is 3 W over 4 hours.

Figure 170 *Magnet Pressure Regulation Scheme*



The MSUP will stay in "hardware control mode" until the average heater power value or the whole MSUP is reset, which also resets the set-point back to 15.3 psia (see also following section "Reset of Pressure Heater Average Power Value").

NOTE The pressure regulation circuit is protected by fuse F7. It will blow after 2.25 hours of continuous pressure heater operation.

Manual Mode

The pressure heater can be turned on manually with the MSUP Hand Display as a means to quickly build-up magnet pressure. When enabled manually, the duty cycle is 100% = approx. 30 W!!!. If forgotten, a timer switches off automatically after 50 minutes.

Safety Mode

If the magnet is almost fully depressurized (0.2 psig above atmospheric pressure), the He-compressor is turned-off by the pressure switch of the Pressure Control Unit to avoid under-pressure.

Parameter	Specifications
max. Pressure Heater duty cycle for normal operation	20 %
Pressure Heater duty cycle in manual mode	100 %
max. Pressure Heater ON time	50 min.
System pressure high alarm	18.0 psia
System Pressure low alarm	15.0 psia

Pressure Heater Average Power Value

The MSUP constantly monitors the required pressure heater average power value (PHAP). This value, shown in SeSo under Magnet&Cooling > Magnet Status or at the MSUP Hand Display is displayed in Watts over a time period of 4 hours and provides diagnostic information about the performance of the pressure control system and Cold Head.

During normal magnet operation, assuming the cold head is recondensing fine and there is no leak, a **typical PHAP of approx. 0.5 - 0.8 W/4 hours** can be seen. This value is slightly magnet- and cold-head dependant and therefore recorded in the SMT Magnet Acceptance Document as **"Recondensing Margin"** value. Please note that this value can change during the day depending on the customers' system usage.

Unusual high or low PHAP values may indicate a magnet problem, e.g.:

- Magnet Leak (PHAP increased)
- Poor Cold Head performance (PHAP decreased)

Reset of Pressure Heater Average Power Value

After any service activity which may temporarily increase the PHAP value above normal (e.g. depressurizing, LHe-filling, etc...) the PHAP values must be manually reset to avoid that the MSUP falls into hardware control mode (see also description page 230).

The following steps need to be done at the MSUP Hand Display:

- Turn-on pressure heater manually until 15.4 psia is reached
- Turn-off pressure heater

NOTE When the MSUP power is turned-off, the Pressure Heater Average Power Values are also reset.

Magnet Temperature Monitoring

The following magnet temperatures can be checked by the MSUP:

- 50 k Magnet Cold Head
- 50 k Shield Temperature (1-Link, 1-Bore, a second set of sensors exist but must be jumpered on the MSUP)
- Turret Temperature (2-Fixed Current Lead = FCL)
- 4 Carbon or Ceramic Resistors - the resistors are at different heights within the magnet

Temperature measurements are achieved by passing a constant current through the diode sensors or carbon resistors and measuring the voltage drops. The measured values are checked against standard parameters stored in its memory. Some of the parameters can be set under SeSo > Magnet & Cooling > Initialization or Alarm Settings).

Temperature Monitoring Specifications

Parameter	Specification
Cold Head Temp Sensor	
Sensor alarm	1060 mV / 66.1 k (Cold Head)
Sensor warn	1073 mV / 56.4 k (Cold Head)
Shield Temp Sensors	
Shield temp 1 alarm	1024 mV / 92.30 k (50 k Link)
Shield temp 1 warning	1050 mV / 73.57 k (50K Link)
Shield temp 2 alarm	1012 mV / 100.57 k (50K Bore)
Shield temp 2 warning	1039 mV / 81.65 k (50K Bore)
Carbon Resistors	
Sensor 1 alarm	600>mV>2000 (Carbon Resistor 1)
Sensor 2 alarm	600>mV>2000 (Carbon Resistor 2)
Sensor 3 alarm	600>mV>2000 (Carbon Resistor 3)
Sensor 4 alarm	600>mV>2000 (Carbon Res. He gas)
FCL Temp Sensors	
FCL Sensor 1 alarm	1044>mv>2000
FCL Sensor 2 alarm	1044>mv>2000

Zero-Field Detection

The MSUP contains a sensor to detect the absence of the main magnetic field.

Quench Detection

The newer MSUP can sense a magnet quench by means of detecting **coincidence of zero field and high magnet pressure**. This event is forwarded to the Alarm Box which triggers an external alarm contact (see also page 237). In addition to that, the MSUP will write a **quench log file** which can be downloaded for further quench diagnostics. To **reset** the quench log, the file must be captured with a PC at the MSUP RS232 port (command "VQ", see Troubleshooting Guide).

NOTE Service activities like fitting the pressure service tool at no field can cause undesired triggering of the MSUP quench detection system.

Low Voltage Quench Detection LVQD

Newer magnets provide several Low Voltage Quench Detection sense lines by the turret connector to connector X14 of the MSUP K2256B. In the event of a quench, the voltages across individual magnet coils are recorded in a MSUP logfile to provide further diagnostics for SMT magnet service.

NOTE For downloading of MSUP log files, please refer to the description in the Troubleshooting Guide.

MSUP Layout

Fuses

Fuse	Rate	Description
F1	125 mAT	EIS Control
F2	4 AT	+36 V MSUP supply
F3	500 mAT	LHe-level probe
F4	5 AT	Battery Supply
F5	3 AF	Quench Heater 1
F6	3 AF	Quench Heater 2
F7	3 AF	Pressure Heater Control
F8	375 mAF	Switch Heater

LEDs

LED	Location	Description
yellow	Top of MSUP box	Pressure Heater on
green		+36V MSUP supply voltage present

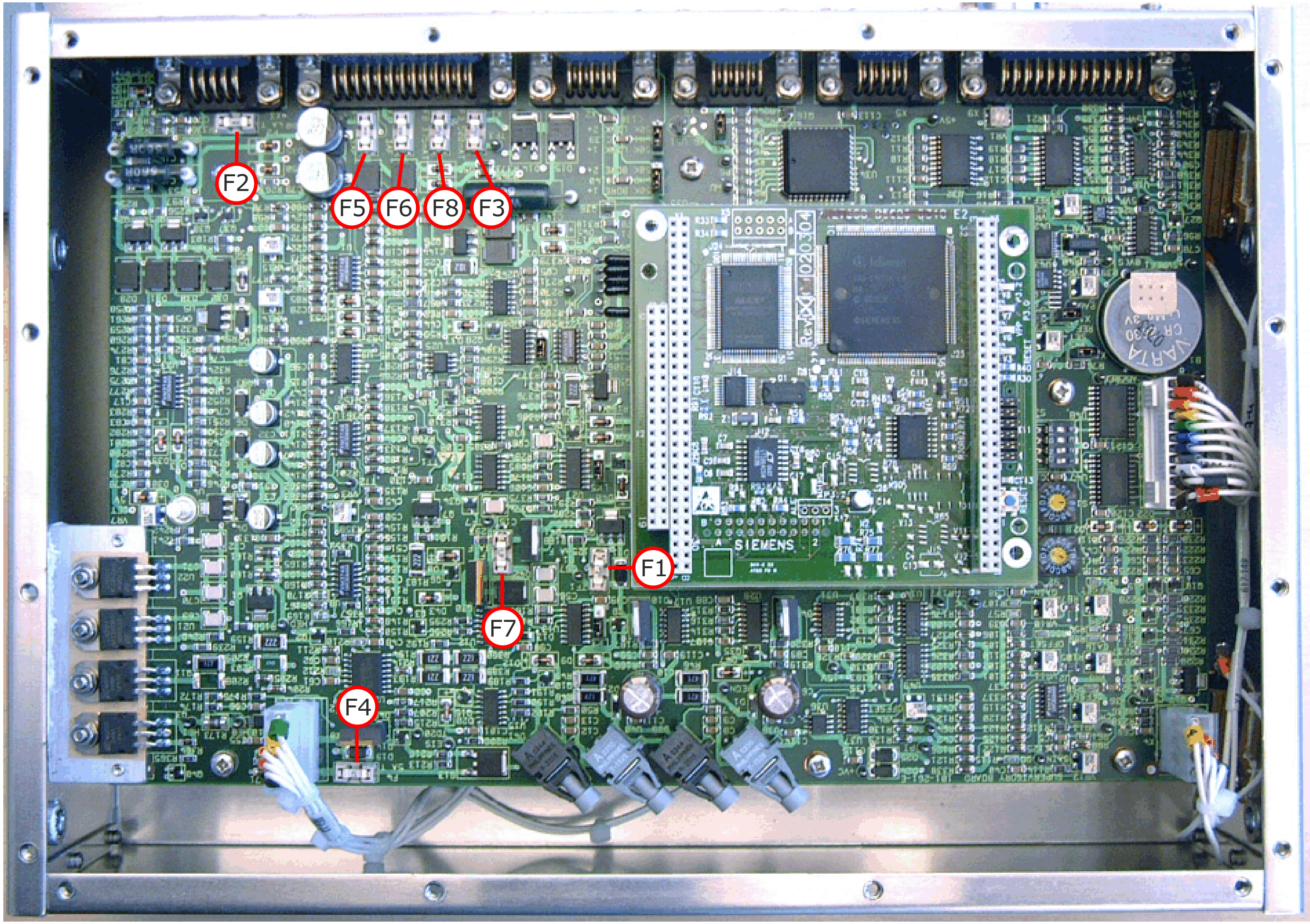
Switches

Switch	Location	Description
S7	Inside MSUP	Set to number of connected ERDU buttons

Jumpers

Jumper	Normal Position	Description
LK1	1 - 2	50K Link Temp Sensors 1 and 2 1 - 2 = Sensor 1 2 - 3 = Sensor 2
LK2	1 - 2	50K Bore Temp Sensor 1 and 2 1 - 2 = Bore Temp Sensor 1 2 - 3 = Bore Temp Sensor 2
LK3	2 - 3	Delay EIS Crowbar 1 - 2 = Test mode 2 - 3 = Normal mode
LK4	1 - 2	Hardware Pressure Control 1 - 2 = Enabled 2 - 3 = Disabled
LK5	2 - 3	Pressure Heater Crowbar 1 - 2 = Test mode 2 - 3 = Normal mode
LK6	1 - 2	Magnet Field Sensor 1 - 2 = use internal sensor 2 - 3 = use external sensor.
X10	jumpered	For Development purposes only Disables data logging to EPROM
X11	jumpered	For Development purposes only Disables the ADC reference volt

Figure 171 MSUP Layout



Block Diagram

Alarm Box

Overview

The Alarm Box is a user interface for:

- **Power switching of the MR-system**
- **Magnet Supervision Indicators**
- **Remote control of He-Compressor**
- **ERDU**

System Power Switching

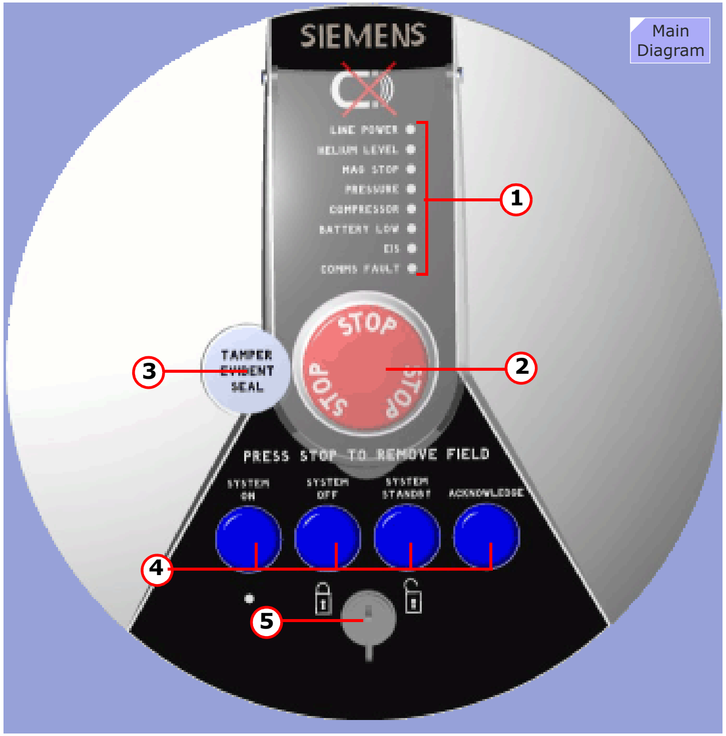
The **System On** and **System Off** buttons are hard-wired to relays k10 and k11 in the Power Distributor responsible for these functions.

When the **System Standby** button is depressed, a command is sent to the Host over a serial communication line. The Host in turn shuts the Imager down, after which the Host sends back a command to the Alarm Box over the same serial line to activate the System Standby signal to the PDS (relay k13). See Figure 204 for more details.

Buttons

Switch	Description
SYSTEM ON	All MR-System components are powered up
SYSTEM OFF	All MR-System components are switched off
SYSTEM STANDBY	All components except host are switched off
LOCKING KEY	To prevent from unauthorized power switching
STOP BUTTON	Emergency Run Down Unit (ERDU) for magnet
ACKNOWLEDGE	Resets error latch and buzzer

Figure 172 *Alarm Box Front Panel*



Pos. 1 Status and error LEDs

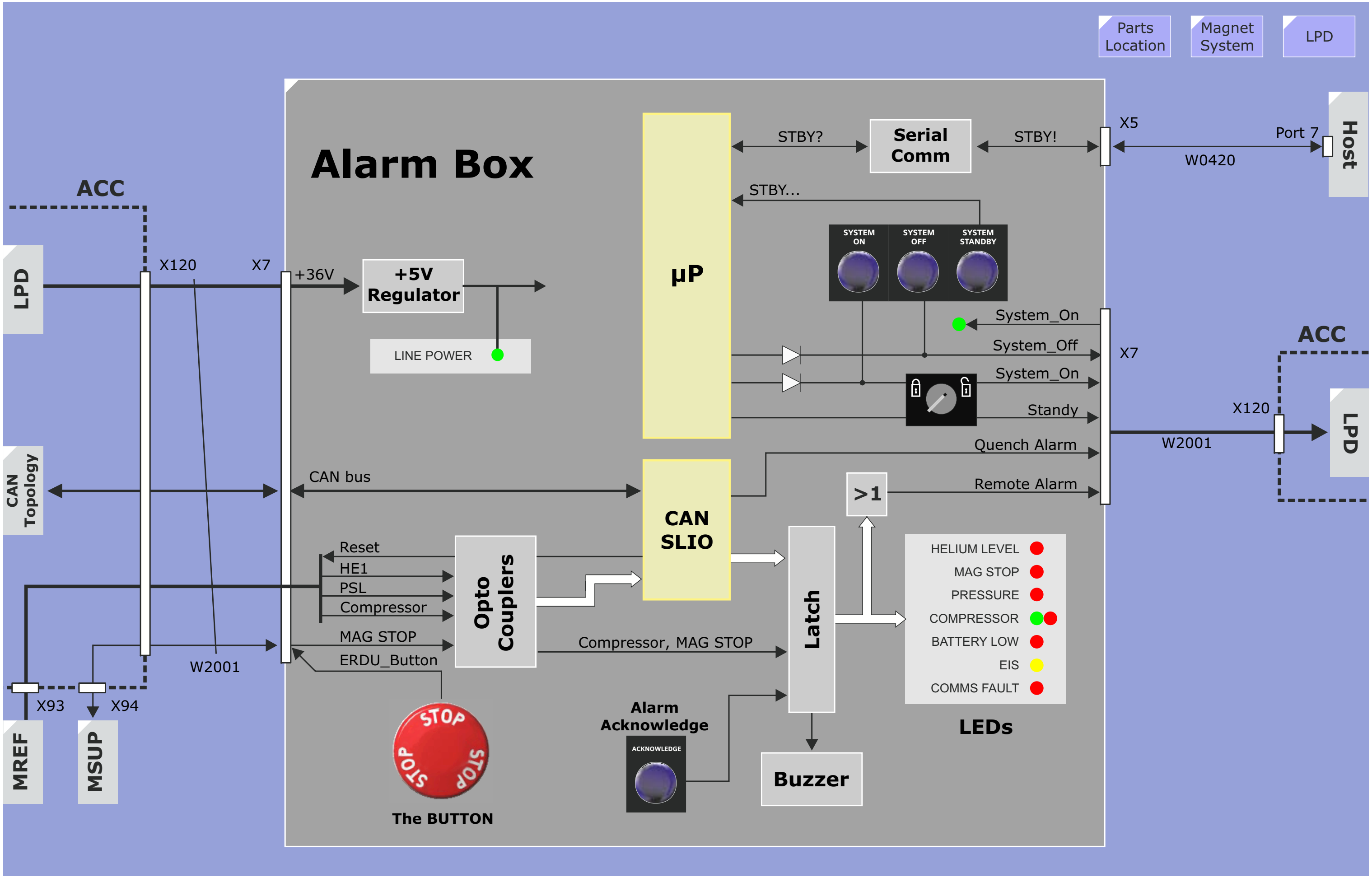
Pos. 2 ERDU button

Pos. 3 Tamper-proof seal (replaces Tell Tale function)

Pos. 4 System power switches and alarm acknowledge

Pos. 5 Power switch locking key

Figure 173 *Alarm Box Block Diagram*



Status Indicators

LEDs

LED	Description
LINE POWER	Power is applied to the Alarm Box
HELIUM LEVEL	Helium level alarm (< 40%)
MAG STOP	Quench / Switch Heater fault or ERDU button / battery fault
PRESSURE	Magnet pressure too high / low
COMPRESSOR	Green = compressor running Red = compressor has stopped by fault
BATTERY LOW	ERDU battery voltage < 23.25 V
EIS	Fault in the External Interference Screen circuit
COMMS	To ensure the integrity of the communication link, the MSUP triggers a watchdog at the Alarm Box. When communication is down for more than 10 seconds, the watchdog triggers the "COMMS" error.
System On	indicates the system is on

Customer Alarm

The Alarm Box supplies an external **customer alarm contact**, that is triggered in case of:

- HELIUM LEVEL too low
- BATTERY LOW
- COMPRESSOR OFF (only power faults, no temperature errors)
- MAGNET PRESSURE too low
- SHIELD TEMPERATURE too high

In case of alarm, the Alarm Box activates relay K17 in the Line Power Distribution system. Galvanically isolated contacts are supplied to the customer over connector **X119 at ACC roof** (for description see table of connectors).

NOTE The Customer Alarm can be reset by pressing the "ACKNOWLEDGE" button.

Quench Alarm

The newer MSUP 2657B can sense a magnet quench by means of detecting coincidence of zero field and high magnet pressure. This event is forwarded to the Alarm Box which triggers relay K19, available at newer power distributors. Galvanically isolated contacts are provided via **X119 at ACC roof**. The customer may connect an external alarm device there to get informed about a quench.

Alarm Buzzer

In case of a relevant error, the Alarm Box buzzer will sound to inform the operator. The buzzer can be reset by pressing the "**ACKNOWLEDGE**" button.

NOTE For certain self-resettable faults, e.g. compressor errors, the alarm buzzer stays on when the Warning LED is already reset. This is normal behavior. The buzzer can be reset with the "ACKNOWLEDGE" button.

Compressor Control

The Alarm Box is connected via connector X7 to X120 at ACC roof. Various compressor related signals are routed via that cable harness. A connection via X93 ACC to the EXT. JR connector of the compressor connects the discrete signal lines for:

- Compressor status and error signals
- MSUP compressor reset signal
  (20 min. after power-, water- and temperature-failures)
- Compressor switch-off signal
  (in case pressure control detects a low magnet pressure)

Compressor related status and error signals are communicated via CAN0-bus connection to the MSUP and host.

See Figure 181 for wiring diagram of the compressor remote control

NOTE The newer version of the Alarm Box (part.no. 100 96 765) has a 20 min. timer to delay the compressor on signal to inhibit frequent switching.

ERDU Stop Button

Two functional parts of the Emergency Run Down Unit (ERDU) are located at the Alarm Box:

- Red ERDU "STOP" push button
- Red "MAG STOP" LED

When the ERDU button is pressed in case of emergency, the MSUP energizes the quench- and switch-heaters of the magnet, resulting in a quench of the super-conducting magnet coil. The magnetic field decays immediately. To protect against accidental operation, the button cover is protected by a seal. The seal must be replaced after operation of the button.

Advanced High Order Shim

Overview

With help of this option the local magnetic field inhomogeneities caused by the patient can be improved. On Espree magnets with SN <30555 it is also used to ramp the Z2 supercon shim coils. It is standard on all Espree systems, and optional for Avanto systems.

Passive shimming with iron plates reduces low and high order inhomogeneities caused by magnet tolerances and ferromagnetic components in the environment. Patients (and phantoms) also cause local field inhomogeneities that have to be compensated for those applications sensitive to inferior shim, e.g. Spectroscopy, FatSat, EPI (Echo Planar Imaging), TGSE (Turbo Gradient Spin Echo).

The correction of linear inhomogeneities is done via offset currents applied to the gradient coils. Second order inhomogeneities are compensated by applying currents to 5 shim coils that are integrated into the gradient coil:

- A(2,0)
- A(2,1)
- B(2,1)
- A(2,2)
- B(2,2).

(see also Tune-up, Phantom Shim)

Customers who want to make use of these shim coils have to purchase the Advanced High Order Shim that consists of:

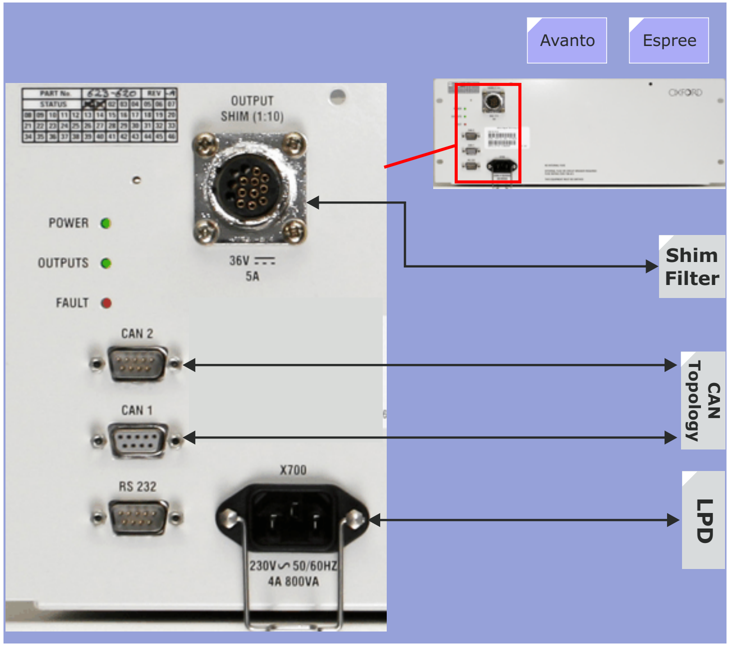
- **Shim Power Supply Unit (SPS)**
- **Shim Filter Unit**
- **Shim cables**

The SPS is mounted inside the ACC cabinet, the Shim Filter Unit is installed on the filter panel.

After installation of the hardware, the Advanced High Order Shim option has to be enabled in the syngo MR configuration.

Shim Power Supply (SPS)

Figure 174 *Shim Power Supply Unit*



General

The SPS is a self-contained unit mounted inside the ACC cabinet. It comprises one large printed circuit board containing most of the electronic parts and a small display board for front panel connectors and LEDs. The base of the unit contains two switched-mode power supplies and a cooling fan, together with a wiring loom and structural metal components.

Function

Five built-in switch-mode DC/DC converters are responsible for producing the shim currents for the 5 shim coils. The maximum current that can be supplied per channel is 5A at a maximum output voltage of +/- 20 V. Current regulation is based on the principle of Pulse Width Modulation.

Shim currents are setup under syngo MR in the Tune-Up step "Phantom Shim". They are loaded automatically into the SPS via its CAN-bus connection. If required, these shim currents can be optimized temporarily for a patient measurement with help of the 3D-Shim. The SPS is able to report its status via CAN commands to syngo MR, i.e. error messages can be seen in the eventlog.

Specifications

5A Shim Power Supply Unit 2362	Specification
Weight:	13 kg (28.7 lb.)
Maximum magnetic field:	0-5 mT (50 Gauss)
Ambient temperature:	+15 °C to +35 °C (59 °F to 95 °F)
Relative Humidity:	20-80% non-condensing
Cooling:	air-cooled, internal fans
Line voltage:	198-253 VAC, 50/60 ±1 Hz
Input power	< 0.8 kVA
Maximum current per channel:	±5 A DC, simultaneously on all channels
Settling time for change from +5A to -5A:	< 0.15 sec. for 1 channel < 0.5 sec. for 5 channels
Current drift due to self-heating:	< ± 5 mA change from initial current
Power dissipation:	< 250 W all outputs at 5 A, 20 V
Shim coil inductance:	<10 mH
Shim coil resistance A20: All other coils:	<1.5 Ohms <2.0 Ohms

Connectors

Shim PSU-channel#	Shim-coil	Shim filter-Pin#	Shim connector-at gradient coil; Pin#
Channel 1 +	A20 +	1	14
Channel 1 -	A20 -	2	24
Channel 2 +	A21 +	3	1
Channel 2 -	A21 -	4	3
Channel 3 +	B21 +	5	10
Channel 3 -	B21 -	6	12
Channel 4 +	A22 +	7	26
Channel 4 -	A22 -	8	28
Channel 5 +	B22 +	9	35
Channel 5 -	B22 -	10	37

LEDs

LED	Description
POWER, green	if lit, SPS is standby
OUTPUTS, green	Shim Outputs are switched on
FAULT, red	Error has occurred

Shim Filter Unit

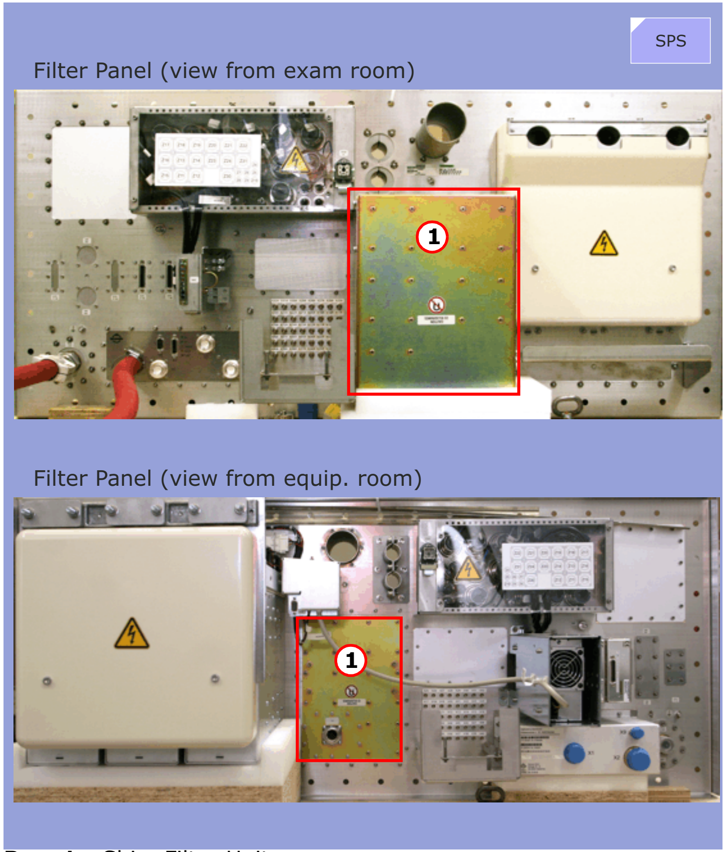
Function

To supply the shim coils of the scanner inside the examination room, the output leads of the SPS are fed through a RF filter box, mounted at the filter plate. By that means, external interferences riding on the outside shim cables can not pass into the RF-cabin. The filters also protect the SPS from voltage transients induced by the gradient coil.

Specifications

Shim Filter Unit	Specification
Weight:	23 kg (50.7 lb.)
Maximum magnetic field:	0-10 mT (100 Gauss)
Cooling:	air-cooled, convection
Resistance of Filter Unit plus Cables:	< 1.2 Ohm, per channel
Power dissipation:	< 88 W all outputs at 5 A

Figure 175 *Shim Filter Unit*



Pos. 1 Shim Filter Unit

Z2 SuperCon Shim

NOTE	Found on Espree magnets below SN 30555 only. Newer Espree magnets have been modified internally to eliminate the need for the Z2 supercon shim coil.

Overview

In order to reduce the necessary amount of shim iron, the MAGNETOM Espree magnets below SN 30555 were equipped with a super-conducting Z2-shim system that consists of:

- Super-conducting **Z2 Shim Coil** that is part of the magnet coil and equipped with a Z2 switch heater
- **Shim Power Supply Unit** (SPS) - Same type as for Avanto
- **Shim Interface Unit** (SIU) - Connects the SPS either to Resistive Shim Coils or to the Supercon Shim
- **Shim Filter Unit** and Cables
  Same type as for Avanto

The SuperCon Shim needs to be energized at the beginning of the OR122 shim process. During the procedure, the Shim Power Supply output cables to the Resistive Shim Coils are temporarily connected to the Z2-SuperCon Shim coil by changing a dedicated cable connection at the Shim Interface Unit (SIU). In that mode ("SuperCon mode"), the Shim Power Supply is used to alter the current running in the Z2 shim coil and to control the Z2 switch heater. The site-specific Z2 shim current value is calculated and initially loaded by the shim program into the service software. After the SuperCon Shim is energized, it remains persistent at field and the operator can re-establish the original SIU cable configuration to "Resistive Shim".

NOTE	For a detailed description of the SuperCon shimming procedure, please refer to SESO/Online Help/Shim.

Z2 Shim Coil

Shim Field

The super-conducting Z2-shim coil is designed to generate a magnetic correction field to compensate for second order inhomogeneities of A(2.0) type.

Z2 Shim Coil Assembly

The Z2-shim coil is mounted inside the cryostat close to the main magnet coil. It is electrically shorted by a super-conductive switch. A 0.2 ohm dumping resistor is connected across the switch.

Z2 Coil Control

For changing the Z2-Shim current, its switch needs to be opened by a 100mA heater current supplied by the Shim Interface Unit (SIU). Switch heater control and Z2 shim current supply are handled by the Shim Power Supply Unit (SPS).

Z2 Shim Current Reset

During ramping of the main magnet coil, a current may be induced for the Z2-shim coil. To avoid the risk of a Z2-shim quench with possible knock-on quench of the magnet, the SIU activates the Z2-switch heater during ramping. The Z2-current is absorbed by the 0.2 ohm dumping resistor (located inside the cryostat).

Specification

Parameter	Specification
Default Z2 coil sensitivity @ 45 cm DSV	±280ppm @ ±20A
Max Z2 heater warm-up time	60 sec.
Max Z2 heater cooling time	60 sec.
Max Z2 coil current settle time	60 sec.

Shim Power Supply Unit (SPS)

General

The SPS is identical to the device used in the MAGNETOM Avanto. Nevertheless, for Espree systems the SPS can work in two different modes that are determined by a configurable cable set-up at the Shim Interface Unit (SIU):

- Resistive Mode
  The "standard" mode with 5 shim output channels connected to the 5 resistive shim coils.
- SuperCon Mode
  SPS output channels are connected to the super-conducting Z2 shim coil.

Function

Shim Mode Detection

During power-on, the SPS automatically detects the type of shim coils connected. A nominal current of -100mA is set to the output of shim channel 5 (a signal with negative polarity will not activate the SIU Z2-switch heater circuitry).

During this test, the SPS monitors the corresponding voltage drop across the output. A voltage drop of less than 3 volts indicates "Resistive Mode". If the voltage is higher than 3 volts, the "SuperCon Mode" is assumed. A voltage drop of more than 26 volts is considered as output voltage fault with error "disconnected".

Shim Channel Usage

The Z2 switch heater circuitry of the SIU is controlled by shim channel 5. The Z2 shim current is supplied by channels 1-4 that are connected in parallel. Since each of channels can supply up to 5 amps, the possible Z2 shim current is 20 amps maximum. Control of all 5 shim channels is performed via CAN bus commands.

Specification

Parameter	Specification
Max Z2 shim current	±20A (channel 1-4 outputs in parallel)
Max Z2 current sweep rate	3A/sec.
Resistance of load on switch heater nr. 5	50-160 ohms
Nominal current setting at switch heater channel 5	100mA
Test current setting at switch heater channel 5	-100mA
Duration of test for switch heater channel 5	1 sec.

Service Routines

The Z2 SuperCon shim current is initially loaded with a fully automatic sequence during the shim procedure in SESO.

A pop-up window informs the operator to configure the SPS to "SuperCon Mode" by changing its output cable connection accordingly at the SIU. In a second step, the shim program initiates the Z2-coil ramping up sequence at the SPS.

The Z2-switch heater management and loading of the last calculated Z2-shim demand current, based on the measured value of A(2.0) and the shim sensitivity, are performed without further user interaction.

When the procedure is finished, the Z2 SuperCon shim current runs persistently in the coil and the operator is prompted to reconnect the SIU shim cables to "Resistive Mode".

NOTE For a detailed description of the SuperCon shimming procedure, please refer to SESO/Online Help/Shim.

Shim Interface Unit (SIU)

NOTE Found on Espree magnets below SN 30555 only. Newer Espree magnets have been modified internally to eliminate the need for the Z2 supercon shim coil.

General

The Shim Interface Unit (SIU) is an interface between the following

OR122 magnet system components:

- Magnet Supervision (MSUP)
- Shim Power Supply Unit (SPS)
- Magnet Main Coil
- Resistive Shim Coils
- Z2 SuperCon Shim Coil

Function

Shim mode switching

The SIU allows switching the Shim Power Supply Unit outputs to either resistive shim coils for imaging or to the Z2- SuperCon shim coils for service.

Switching is performed manually at the SIU by connecting a flying cable to either plug position X4 ("Resistive") or plug position X5 ("SuperCon").

In the "Resistive Mode", the SPS is connected to the shim coils quite similar to Avanto systems.

In the "SuperCon Mode", SPS channels 1-4 are connected in parallel to the Z2-shim coil (inside the cryostat). Channel no. 5 is fed to the Z2-switch heater control circuitry of the SIU PCB.

Z2 Switch Heater Control

The SIU contains a 100mA driver for the Z2-switch heater that is powered by 36VDC from the MSUP. The SIU does not include a power switch, it is active whenever the MSUP power supply is on.

The heater driver can be operated in two ways:

- SPS output channel no. 5
  During shimming the service software transmits CAN commands to the SPS for Z2-switch heater management.
- Magnet sense voltage
  The magnet coil is connected to the SIU via a sense cable from the FCL. If the voltage exceeds 3 Volts, the Z2 Switch Heater is activated and the Z2 shim current is dumped into a resistive load inside the cryostat.

All control inputs from SPS and from the magnet terminals are opto-isolated from the Z2-heater and from each other.

LEDs

LED	Description
Heater On	Heater activated by SPS channel nr. 5 or by magnet sense voltage >3V (when ramping)

Figure 176 *Shim Interface Unit Schematic*

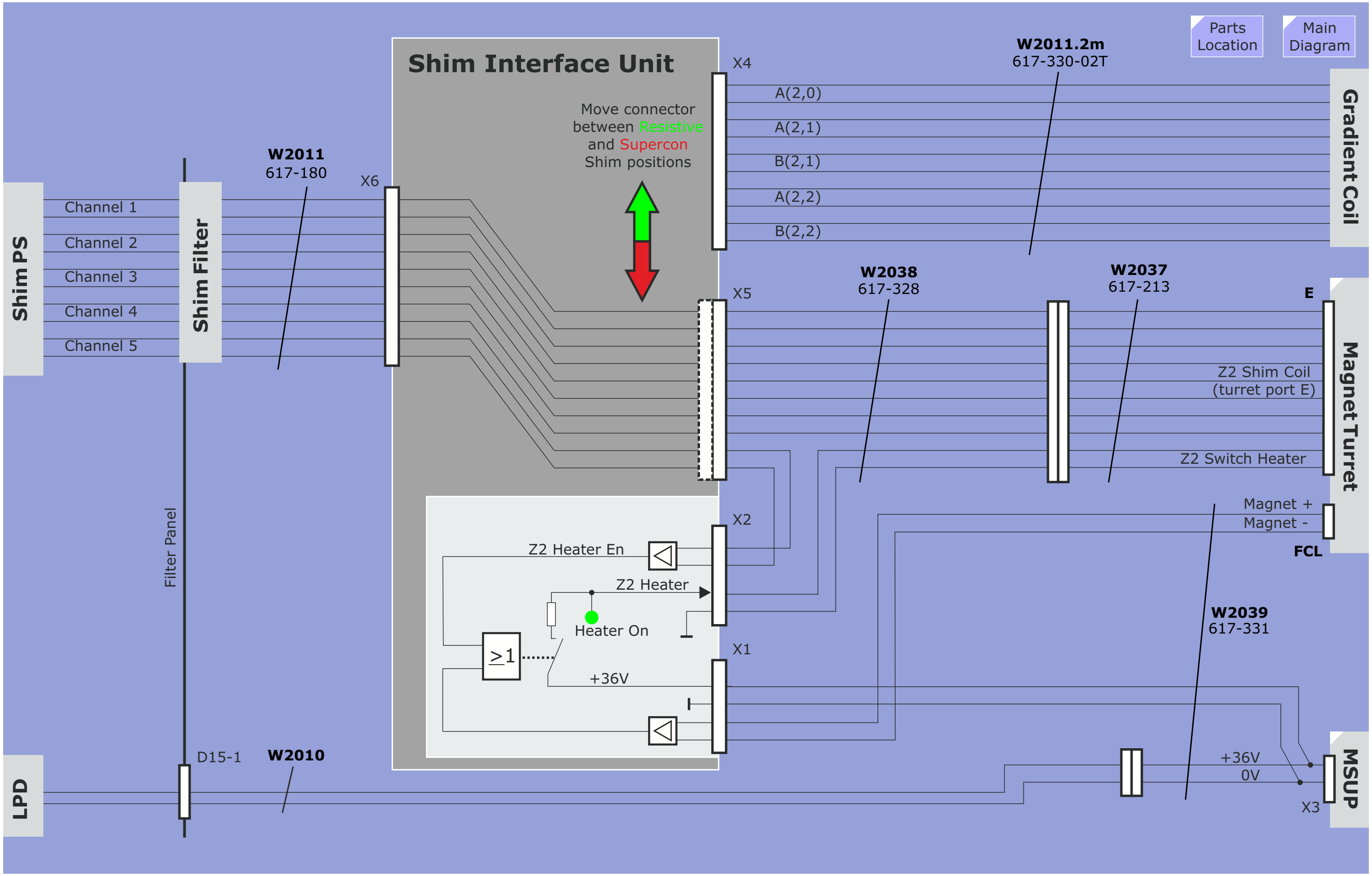
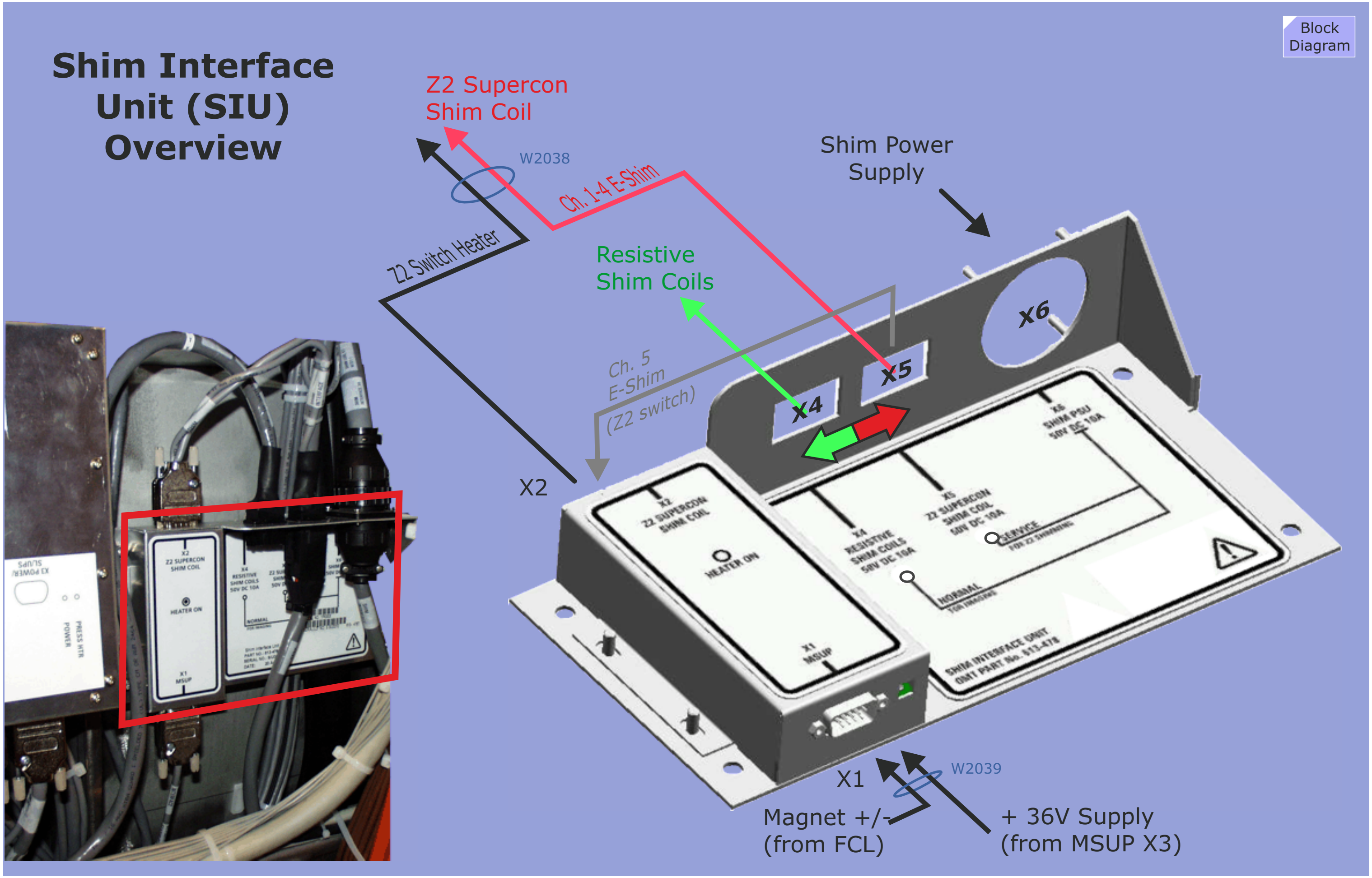


Figure 177 *Shim Interface Unit Layout*



Refrigerator System

Overview

The cryogenic Refrigerator System for the OR105 and OR122 Magnets consists of:

- **Compressor**
  Provides compressed high-purity (oil-free) helium gas for Cold Head operation. The compressor is water-cooled by the cooling system.
- **Cold Head**
  For the liquefaction of the boiled-off helium gas and for cooling of the 50K magnet cryo shield.
- **Flex-lines**
  The connection in between Compressor and Cold Head.

NOTE The medium used in the Refrigeration System is 5.0 helium gas. Use ONLY this gas!

The Compressor and Cold Head are manufactured by SUMITOMO Heavy Industries Ltd., Japan.

Compressor (MREF)

General

The Compressor comprises the modules:

- Compressor capsule
- Heat exchanger
- Gas purifiers
- Control module (electrical supply unit)

There are two units in use on the Avanto and Espree systems:

- **CSW-71W** (up to mid 2007)
- **F-70** (from mid 2007)

Figure 178 *Cold Head Compressors*

CSW71-W Compressor

Function

Compression and Cooling

The compressor pressurizes the helium gas to approx. 21 bar. During compression the gas heats to about 90°C. It is cooled by the heat exchanger using water supplied by the Cooling System. A second heat exchanger cools the compressor’s oil. The temperature of the cooling water should be 15 °C - 20 °C at a flow rate of 6...10 l/min.

Gas Purifiers

After being cooled the compressed helium gas is passed through an oil separator to condense oil vapors and return by means of capillary pipes.

The helium gas exiting the oil separator still contains small quantities of oil vapor. To prevent this oil from freezing inside the Cold Head, an **adsorber** is located behind the oil separators.

NOTE	It is important to replace the adsorber after every 20000 hours of operation (**~ 2 years**)!

Compressor Valves

Two important valves are built into the compressor:

- Over pressure relief valve:
  It opens at approx. 27 bar to protect against over-pressure.
- Solenoid Bypass valve:
  Opens if compressor is switched off to equalize high- and low pressure for Cold Head protection.

NOTE	An open bypass valve is indicated at the compressor service display with a symbol "V".

Monitoring

The following is monitored:

- Over-temperature:
  Of Helium, cooling water and Compressor capsule.
- Helium over-/low-pressure
- Supply voltage faults:
  Wrong voltage/frequency setting, reversed/missing phases.

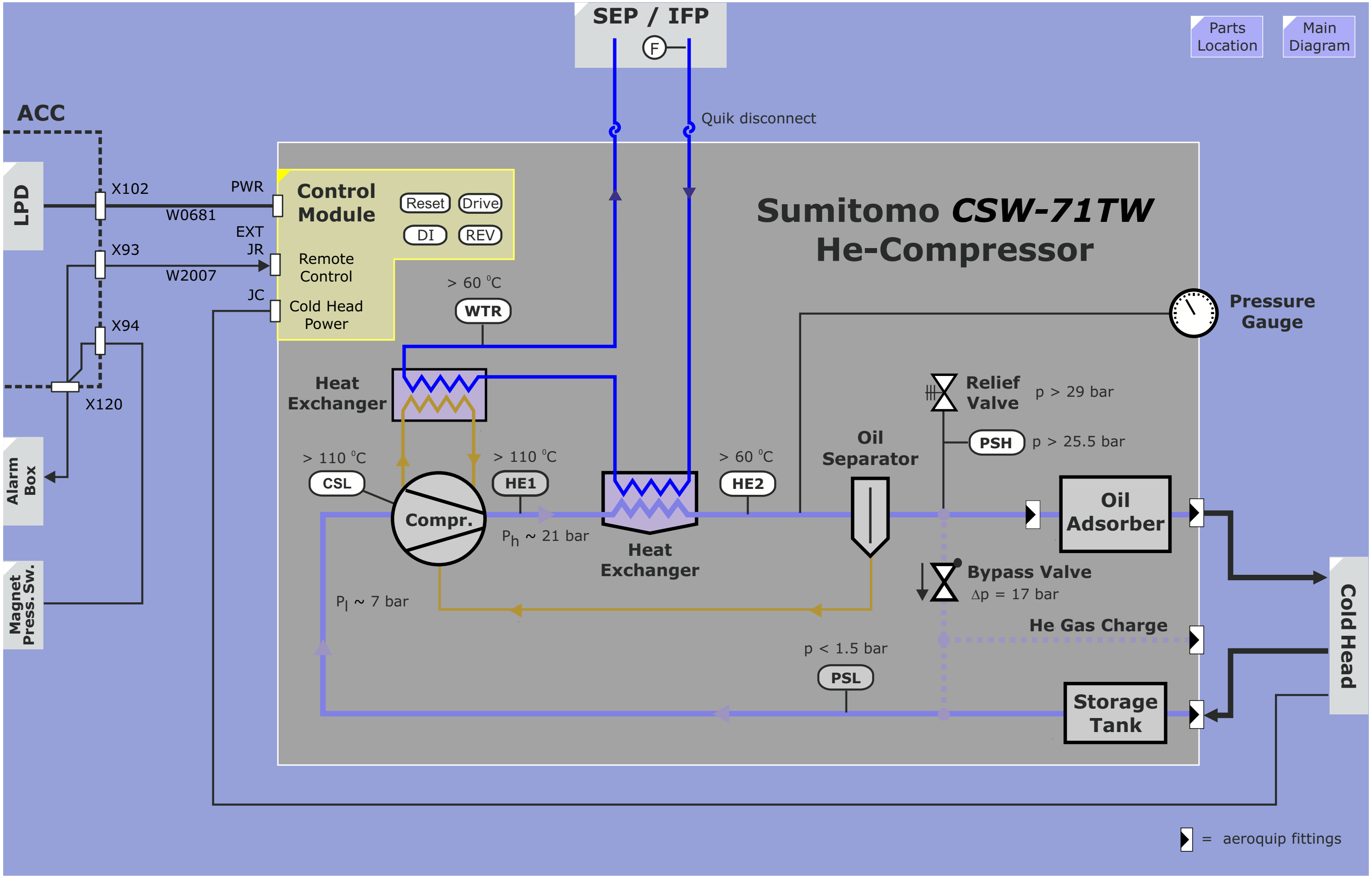
NOTE	If the compressor capsule overheats, it can take 20 to 60 minutes before a compressor reset is possible.

Logged Events

The last 99 error events are stored and can be scrolled through by using the up and down arrows below the display.
Error reporting
Three discrete error signals (see diagram) are also sent to the Alarm Box which informs both the Host and MSUP via the CAN bus. In return, the Alarm Box can send a remote reset signal after power, water and temperature failures to restart the compressor again.

- In case the magnet low pressure switch (Pressure Control Unit) detects a very low magnet pressure (less than "Atmospheric pressure + 0.2 psiG") the compressor will be switched off remotely. The signal is fed into the cable harness from the MSUP through the filter panel and Alarm Box to the EXT. JR connector of the compressor. The Cold Head stops, and helium is no longer recondensed, thus preventing subatmospheric magnet pressure.
- Older systems with SEP option (manufactured before June 2011) have an additional SEP pump interlock ("pump-off" switch N1) to prevent compressor over-heating in case the water pump is off.

Figure 179 *CSW-71W Compressor Block Diagram*



Control Module

The compressor unit is equipped with several monitoring devices to indicate faults. Compressor status and errors are reported to a service display at the front side of the compressor and/or via connector EXT. JR to the Alarm Box. There are three discrete status signals sent to the Alarm Box:

Operating Modes

The Sumitomo Compressor can run in three different modes of operation, to be indicated at the service display:

- INT Mode:
  Compressor & Cold Head can be powered On/Off. Remove the EXT. JR connector first, switch on power. Operation control with "Run" and "Stop" buttons.
- EXT Mode:
  The "normal" operation mode. Compressor & Cold Head On/ Off is controlled by the Alarm Box and SEP. The EXT mode is activated by fitting the EXT. JR connector (Pins 7, 8 closed). Via that connector, the Alarm Box can send a remote reset signal to the compressor after power-, water- and temperature-failures. In addition, systems manufactured before June 2011 have a pump interlock from the SEP which inhibits the compressor in case the water pump is not running.
- Cold Head Mode:
  Not used on the 4K Cold Head.

Power Adaptation

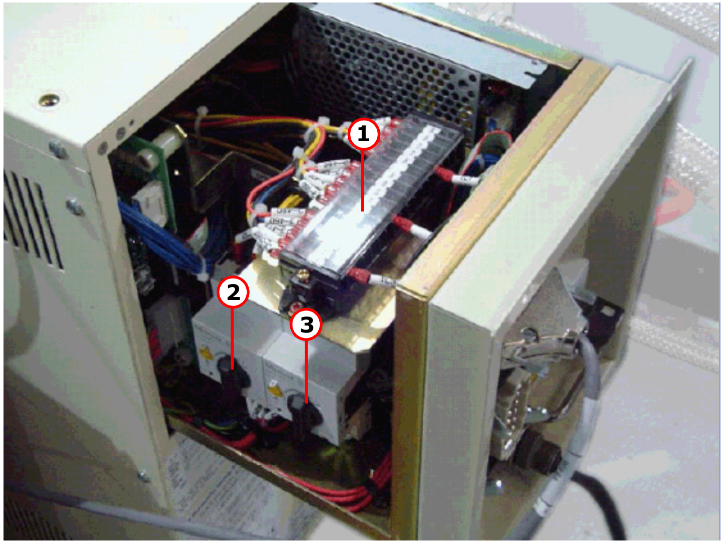
The unit has to be adapted to line voltage and frequency prior to start up. The following voltage/frequency combinations are supported:

- 380-415 VAC@ 50 Hz
- 480 VAC@ 60 Hz
- All other voltages require Stepping transformer option (found under Installation / Options)

Specifications

Value	Specification
Static pressure	16 - 16.5 bar
Dynamic pressure	19 - 22 bar
Cooling water flow	6 - 10 l/min.
Cooling water temperature	4 - 25 ^{0}C
Water filter	< 100 micron

Figure 180 *CSW-71 Power adaptation (Control module out)*

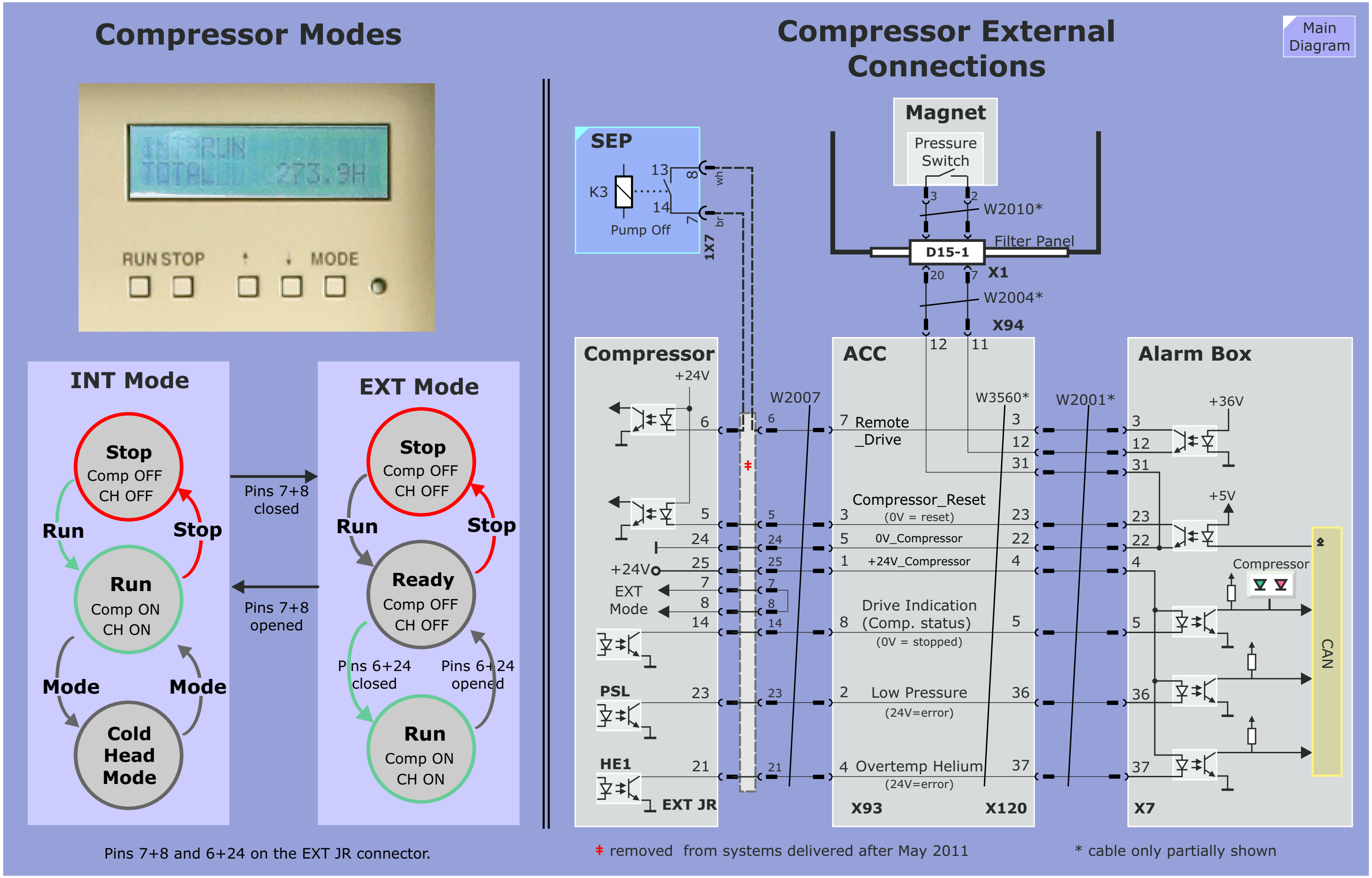


Pos. 1 Power adaptation rail

Pos. 2 Circuit breaker CP1 (Cold Head Motor)

Pos. 3 Circuit breaker CP2 (Cold Head Motor)

Figure 181 *CSW-71W Compressor Remote Control Diagram*



F-70 Compressor

Function

The compressor compresses the helium gas to 21-22 bar. The hot compressed gas is passed through a (dual) water-cooled **heat exchanger** lowering the gas temperature approximately to the temperature of the coolant. The second half of the heat exchanger cools the oil of the compressor capsule.

Oil circulation is maintained by the difference in pressure between low and high-pressure helium.

Downstream from the heat exchanger is an **oil separator** which condenses most of the oil contained in the cooled gas. The oil is returned to the compressor capsule.

The helium gas exiting the oil separator still contains small quantities of oil vapor. To prevent this oil from contaminating the lines or Cold Head an **adsorber**, made primarily of active charcoal, is used.

NOTE It is important to replace the adsorber after every 30,000 hours of operation (**~ 3 years**)!

Compressor Valves

Due to the high gas pressures in the unit several valves are in place:

Valve	Function
Atmospheric Relief Valve (ARV)	Prevents the compressor from operating at an unsafe pressure by venting to atmosphere.
Solenoid Bypass Valve (SV)	Opens if compressor is switched off to equalize high and low pressure for cold head protection.
Internal Relief Valve (IRV)	The internal relief valve opens to allow the compressor to be operated in the stand-alone mode or when the system gas lines are disconnected, to avoid overloading the motor.

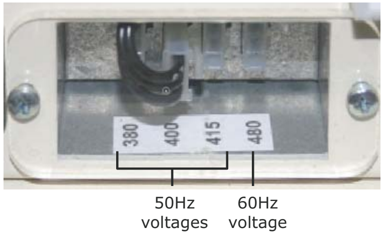
Line Voltage Configuration

The unit has to be adapted to line voltage and frequency prior to start up. The following voltage/frequency combinations are supported:

- 380-415 VAC@ 50 Hz
- 480 VAC@ 60 Hz

All other voltages require Stepping transformer option (found under Installation / Options)

Figure 182 *F-70 Power Adaptation*



NOTE
The unit is factory set for 400V3~50Hz.

Specifications

The compressor is shipped from the factory with a static pressure of 16.5 bar and should be adjusted to the required pressure at installation.

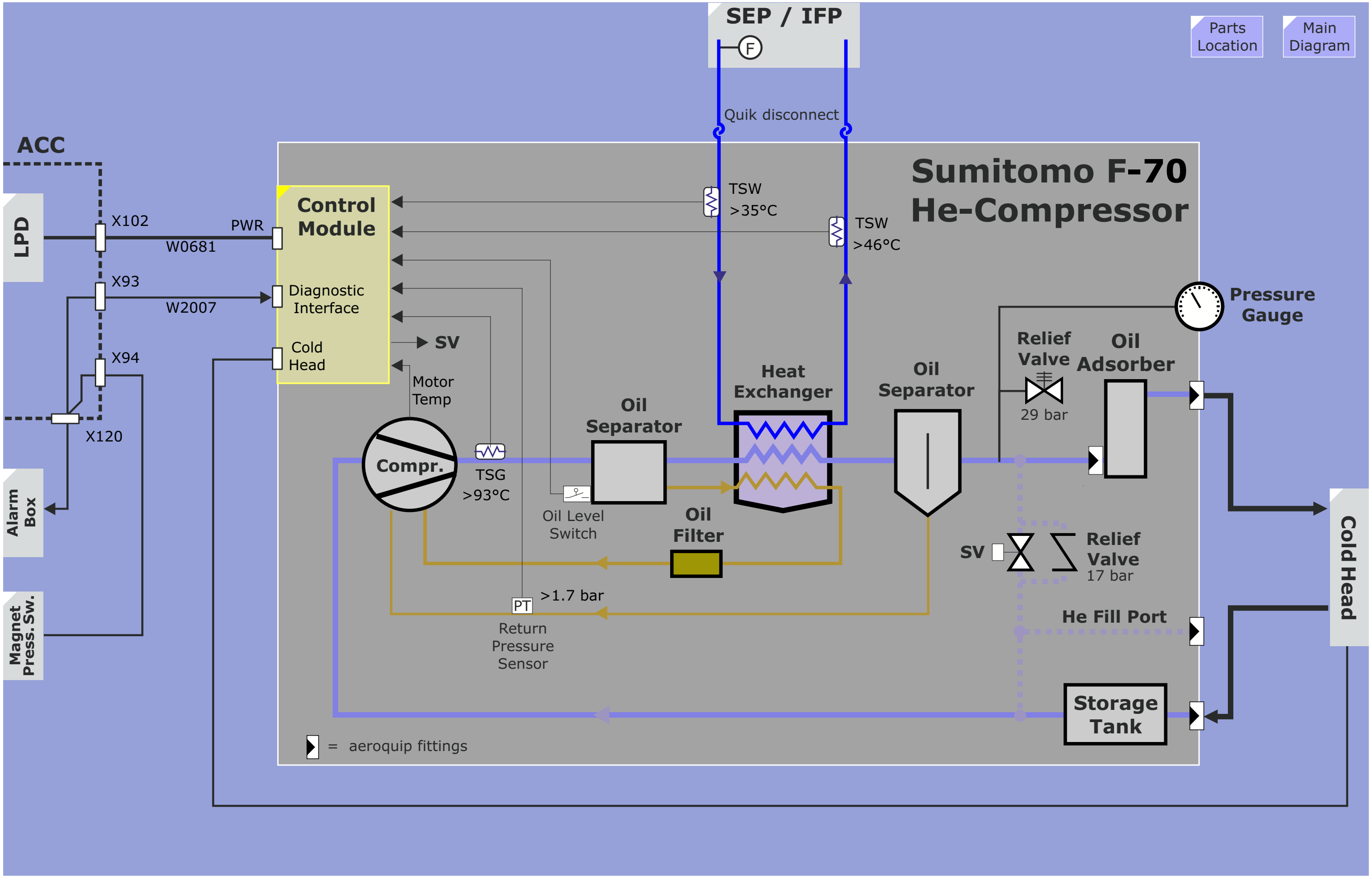
Equalization (static) pressure at 20°C (68°F) for 12 to 20 m long gas lines:

Specification	Value
Cooling water flow rate	6-9l/min.
Cooling water temp	5-25°C
Weight	100kg (220lb)

Cold Head

Version	Static Pressure	Dynamic Pressure
10K 50 Hz	14.3 - 14.6 bar	21 - 22 bar
10K 60 Hz	13.6 - 13.9 bar	21 - 22 bar
4K 50/60 Hz	13.5 - 14.0 bar	21 - 22 bar

Figure 183 *F-70 Compressor Block Diagram*



Control Module

The Control Module is responsible for monitoring and controlling the compressor, solenoid-controlled valves and the Cold Head.

Several sensors in the unit provide monitoring of:

- oil level
- compressed gas temperature
- compressor motor temperature
- return gas pressure
- coolant water temperature

The power to the unit is also monitored internally.

Compressor status and error signals are available at the DB-25 Diagnostic Interface Connector and can be displayed on the units service display located on the front panel.

The compressor ON/OFF status is displayed on the Alarm Box and is recorded in the C:\MedCom\log\MSUPHistory.log file.

Compressor Mode Switch

Configuration	Magnet Type	ON/OFF Switch
Mode 1 (UP)	10K shield cooling	Enabled
Mode 2 (DOWN)	4K re-condensing	Disabled - compressor controlled by 0.2 psi pressure switch

The configuration mode switch is used to configure the output of the DB25 remote control Diagnostic Interface Connector.

NOTE This MODE setting is read when powering on the unit. It can not be changed when the compressor is in operation.

Compressor Control

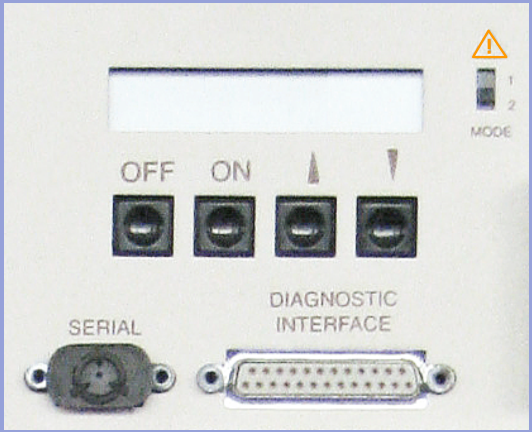
The compressor supplies several inputs and outputs for remote control of the unit:

- **Power-on signal from Alarm Box**
  "Remote Drive" signal is set low if the alarm box is powered and there are no compressor control faults present.
- **Magnet low pressure switch and SEP pump switch**
  The “Remote Drive” signal is fed via the magnet low pressure switch. If magnet He pressure drops below "Atmospheric pressure +0.2-psig", the compressor is disabled to stop the He re-liquefaction process, thus preventing subatmospheric magnet pressure.
  Older systems with SEP option have an additional SEP pump interlock ("pump-off" switch N1) to prevent compressor over-heating in case the water pump is off.
- **Reset signal from Alarm Box**
  To restart the compressor after a power or temperature failure.

NOTE If compressor exceeds temperature limit it may take 20 to 60 minutes for compressor to reset.

Figure 184 *F-70 Compressor Remote Control Diagram*

Compressor Modes

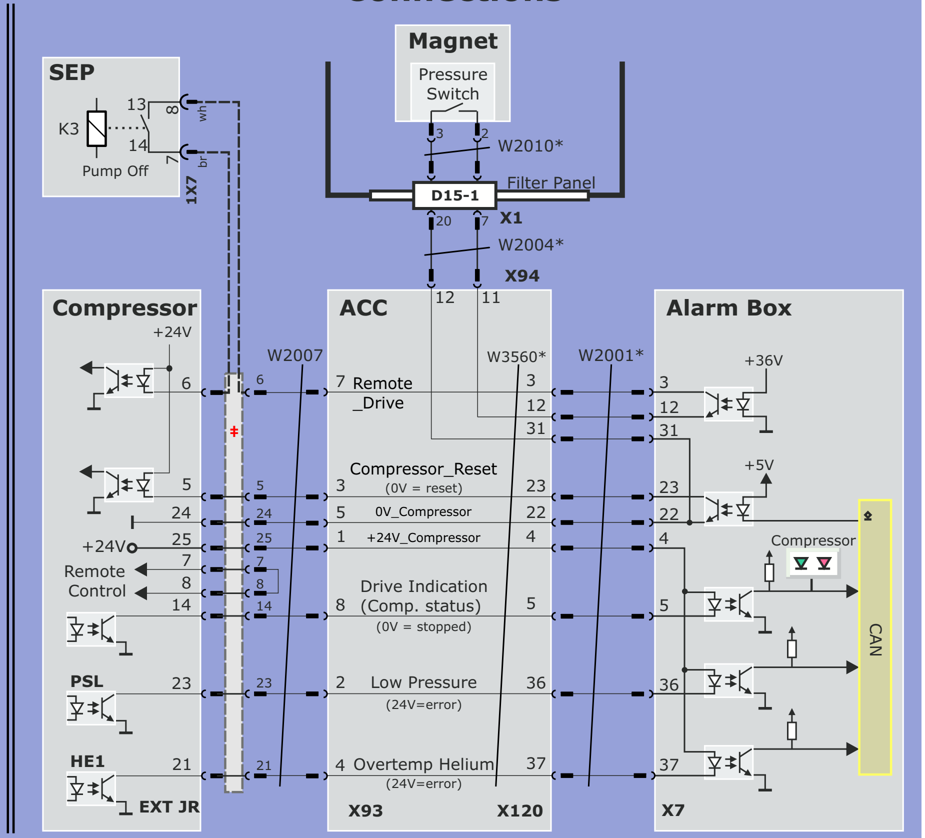


MODE	Magnet Type	ON/OFF Buttons
1	10K Shield cooling	Enabled
2	4K Re-condensing	Disabled

NOTE: In the event of a power failure, K3 (in SEP) will drop out turning off the Cold Head compressor. As soon as power recovers K3 will close again and the compressor will automatically resatart after approx. 2 minutes.

Compressor External Connections

Main Diagram

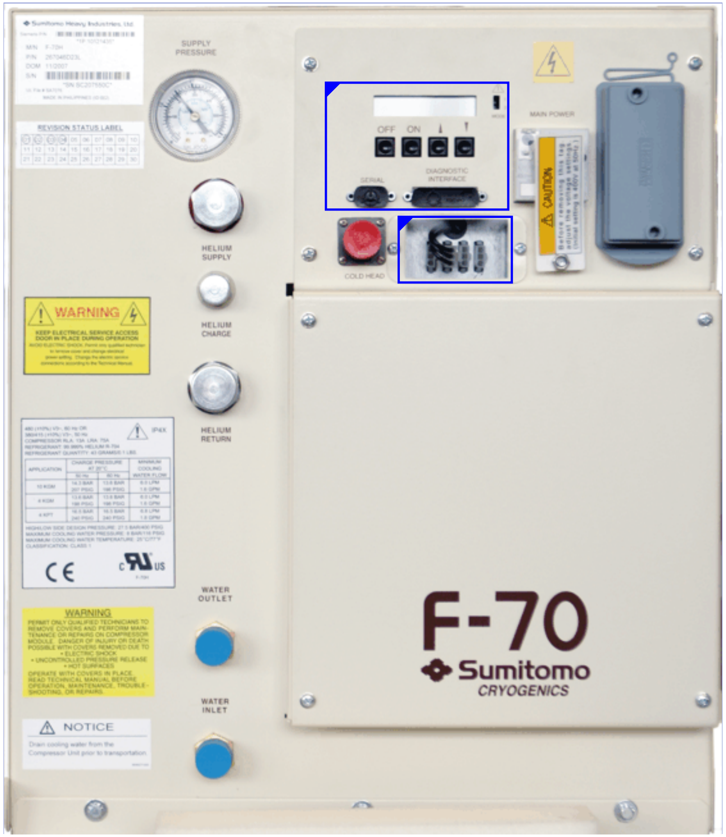


‡ removed from systems delivered after May 2011

* cable only partially shown

Figure 185 *CSW-71 Compressor*

Figure 186 *F-70 Compressor*



Cold Head

General

Heat radiation plays the most important role when considering the heat impact to cryo shield and insulation foils inside the magnet. This heat impact has to be reduced as much as possible, in order to keep the helium boil-off rate as low as possible. That is obtained by cooling the cryo shield to low temperatures around 50 Kelvin, using a Cold Head.

In addition, the Cold Head recondenses any remaining boil-off by cooling the gas to 3.7 Kelvin (He-liquefaction point = 4.2 Kelvin). Providing the heat load to the helium vessel is lower than the Cold Head cooling power, no helium will be lost.

The Cold Head consists of:

- 2-Stage Displacer
- Cylinder
- Drive Assembly
- Motor

Function

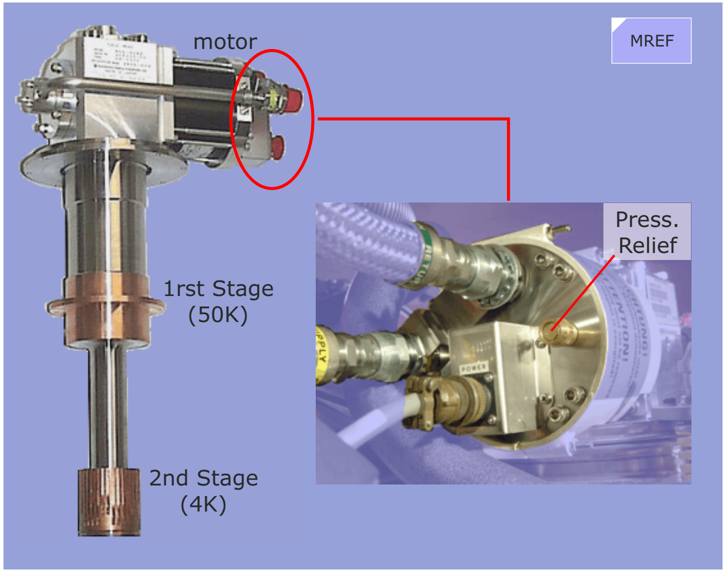
The He-Compressor generates high pressure (approx. 21 bar) helium gas that is supplied via flex-line to the Cold Head. A displacer piston in a metal cylinder, moved by a Scotch Yoke drive and motor, expands the gas according to the Gifford-McMahon principle. The gas flow is controlled and synchronized to the piston movement by a rotary valve, coupled to the motor. The Cold Head is split up into two temperature stages:

- A 50 Kelvin stage (first stage), connected to a single cryo shield.
- A 3.7 Kelvin stage (second stage), sitting within the helium vessel above the liquid level. Any helium gas that boils-off will condense on the second stage and will be returned to the helium pool.

After expansion inside the Cold Head, the low pressure (approx. 7 bar) He-gas returns to the compressor, building up a closed helium gas circuit without losses.

Cold Head, flex lines and compressor are filled and have to be recharged with high purity 5.0 Helium gas (purity better than 99.9990%), otherwise impurities would freeze up inside the Cold Head.

Figure 187 *Cold Head (removed from Magnet)*



Specifications

Value	Specification
Refrigeration capacity 1st stage	50 W @ 30 K - 45 K
Refrigeration capacity 2 nd stage	1 W @ 3.5 K - 4.2 K
Ambient Operating Temperature	5 - 28 ^{0}C
Motor Rotation Speed @ 50 Hz	60 rpm
Motor Rotation Speed @ 60 Hz	72 rpm
Weight	19.5 kg (42.9 lbs)

Service Routines

Disconnecting Gas Lines fron Cold Head

During normal operation the Cold Head contains small quantities of liquid helium inside. When the cold head is turned off this helium will expand resulting in high pressures that can damage the cold head (the PRV could stay open too long leading to contamination).

The gas lines will provide a sufficient buffer if they are left connected. Therefore, to avoid contamination when gas lines need to be removed:

- turn the compressor unit OFF and wait a minimum of 30 minutes to allow for the gas expansion
- disconnect the gas lines from the cold head and fit the Aeroquip connections with dust caps

WARNING

Damage to the cold head occurs if sufficient time is not allowed for the gas to expand in the refrigeration circuit.

Wait a minimum time of 30 minutes before disconnecting the gas lines.

Disconnecting Gas Lines at Compressor

In case the helium flex-lines at the Cold Head- or compressor-side have to be disconnected, special attention has to be paid to avoid Cold Head damage:

- After switching-off the compressor, its internal Solenoid bypass valve will open and allow equalization of high- and low-pressure inside the Cold Head. The flex lines can be removed on the compressor after some minutes.

Figure 188 *Cold Head (with bypass line)*

NOTE Removing the helium flex-lines at the compressor does not require installation of the pressure bypass line.

Section

9 Cooling System

Introduction

The ever increasing power-delivering capabilities of newer gradient and RF components puts and equally increasing demand on the cooling system to provide adequate cooling in order to maintain a constant performance as well as preventing undesirable melt-downs. As the Avanto was still a twinkle in the marketer's eye it could already be foreseen that the new power components (mainly the gradient system) would pose new hurdles for the cooling system guys. Their task was to produce a cooling system that not only would do justice in its responsibility as keeper of thermal equilibrium in a very heated environment but also to come up with a solution with increased capability, increased reliability, reduced manufacturing costs and reduced life-cycle costs. It was evident, a new cooling concept was required.

Actually, the design of this new cooling system has a little brother, the GRACCO of the Concerto system. Similar problems confronted the cooling specialists when specifying out the Concerto's cooling system. The solution found for the Concerto held out much promise to be the solution for the latest high-end MR systems.

The solution is an enclosed, single-circuit cooling water system.

Benefits:

Instead of two water circuits, a primary and a secondary, a single water circuit **requires only one** pump, one heat exchanger, one regulator and one actuator (motorized three-way valve) all of which are expensive.

Since the water temperature of this cooling system is at 20°C, there is no longer the danger of **condensation** build-up within the electronics cabinets. Also, the need for insulation of hoses and pipes is eliminated, in turn reducing even further the installation costs.

The cooling system is now **enclosed**, the same as the heating systems in your homes, allowing the Chiller to be placed at floors above or below the MR system. A closed water system also overcomes problems of corrosion and algae build-up eliminating the need for water additives and expensive filtering components.

Cooling System Configuration

There are two possible Cooling System variants, both incorporating this new design:

Variant 1

This variant represents the basis factory configuration of Avanto and Espree systems and includes:

- a dedicated 20°C chiller (COCS)
- and an accompanying interface panel (IFP)

The COCS chiller was designed specifically to accommodate the maximum cooling requirements of the new gradient system. It has also been integrated into the MR system in that its internal monitoring provides status feedback to the MR system which are logged into the system's event log. This will facilitate servicing the chiller system parts of which now fall under the responsibility of Siemens service.

Variant 2

The second variant is for those customers wishing to use their own in-house chill water supply or an existing chiller unit in the event the newly purchased system is to replace an existing one, or if they wish to purchase their own chiller. This variant consists of the **SEP** cabinet. The SEP cabinet (Separator) acts as an interface between the customer's chiller and the MR system and uses the same basic cool principle as the first variant.

In both variations, the central cooling functionality is provided by the **ACS** (Air Conditioning System) located in the electronic cabinet.

Figure 190 provides an overview of both variants and their connection to the MR System electronics.

Cooling Load Requirements

The major thermal loading of the cooling system is dominated by the gradient amplifier and the gradient coil and the development of heat in these two components is very different in respect to both time and magnitude. When gradient pulses are applied there is first the quick rise of heat in the semiconductor components in the gradient amplifier followed by the slow rise of temperature in the gradient coil.

Figure 189 *Maximum Power Requirements*

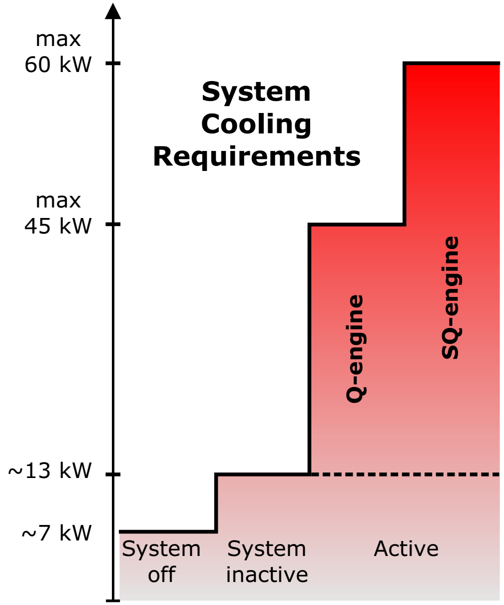
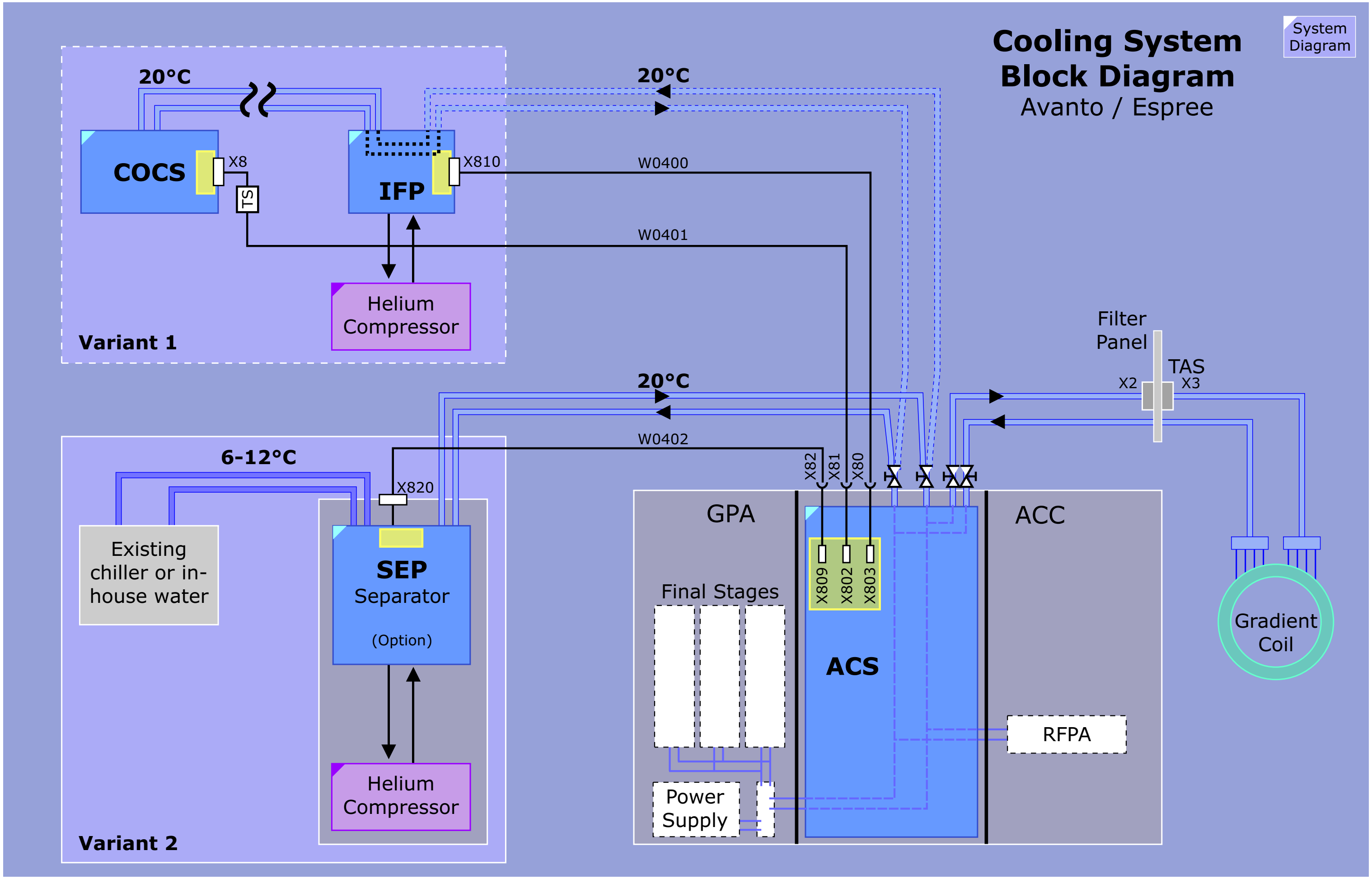


Figure 190 *Cooling System Block Diagram*



Air Conditioning System (ACS)

Overview

The ACS incorporates two functional blocks:

- Cooling water distribution
- ACC/GPA cabinet climatization
- Monitoring

Cooling Water Distribution

The ACS provides the distribution of the 20°C cooling water to all system components requiring cooling water. Since the cooling water is delivered at 20°C there is no danger of condense water and no insulation is necessary. The flows are:

Sub-system	SEP (water)	COCS (glycol)
Gradient Coil		
Flow / cool capacity	25±2 l/min. / <30 kW	30 l/min. / <30 kW
GPA		
Flow / cool capacity	55±5 l/min. / <20 kW	60 l/min. / <20 kW
ACS		
Flow / cool capacity	25±2 l/min. / <5 kW	25 l/min. / <5 kW
RFPA DORA (PORA)		
Flow / cool capacity	10 (16) l/min. / <2 (4) kW	10 (16) l/min. / <2 (4) kW
MREF (compressor)		
Flow / cool capacity	10 l/min. / <8 kW	10 l/min. / <8 kW

There are no valves to adjust to attain these flows. Proper flow to the system components is assured by the diameter of the provided hosing and flow reducers inserted in the cooling water paths. As long as the pump is working properly, the flows will be ok.

Cabinet Climatization

Air Circulation

The blowers located in the Control-Blower Module (Figure 192) draws in warmed air from the GPA and ACC cabinets and forces it over a heat exchanger which is supplied by the 20°C cooling water. The cooled air enters the ACC and GPA cabinets through cut-outs located cut out at the bottom of these cabinets. The ACC has an additional cut-out at its mid-section. Air circulates over the ACC and GPA electronics and drawn into the blowers again through cut-outs at the top of the ACS completing the air circulation path.

Regulation

Regulation of the air temperature is achieved with a 3-way valve (**actuator**) controlled by a PI regulator located on Control Unit N1. Temperature sensor **R1**, a PT100 sensor located at the air outlet, is used as actual value.

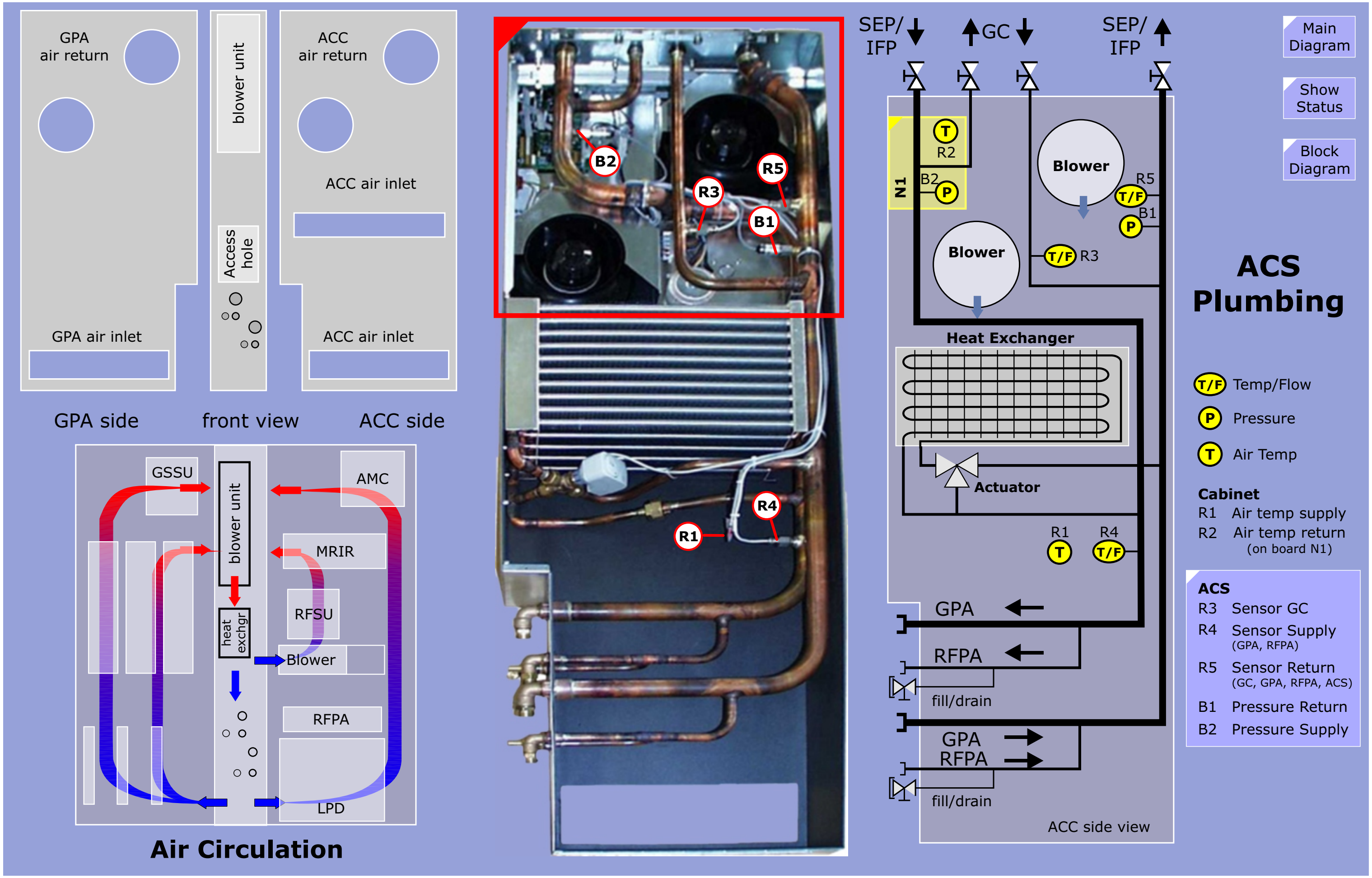
Monitoring

R2 is a PT100 sensor measuring the return air temperature. Temperatures above 38°C give a warning message. Temperatures above 43°C result in an error message. R2 is located directly on the Control Unit N1. The normal temperature lies between 24-28°C.

Monitoring

R3, **R4** and **R5** are PT100 sensors are measuring the water flows through the gradient coil, RFPA/GPA and the total secondary flow respectively. These values are read in and compared to limits which have been determined by the sensor calibration (SeSo > Magnet & Cooling > Initialization > Calibrate Sensor) and downloaded by the MPCU. Error messages are issued when limits are exceeded.

Figure 191 *ACS Plumbing Diagram*



Control Unit N1

The ACS incorporates a control unit N1 which provides these functions:

- monitors cooling air temperature, both intake and output
- regulates the internal cabinet cooling
- monitors cooling water supply pressure and flows
- provides a feedback path of status signals being delivered by the other cooling components COCS, IFP and SEP

The wiring diagram of the ACS in Figure 193 shows the connections of the sensors and actuator used for regulating the cabinet air cooling.

All of the components shown in the diagram, except for the sensors and 3-way valve drive motor M5, are located in a pull-out module found at the top of the ACS.

Figure 192 *ACS Control-blower Module*

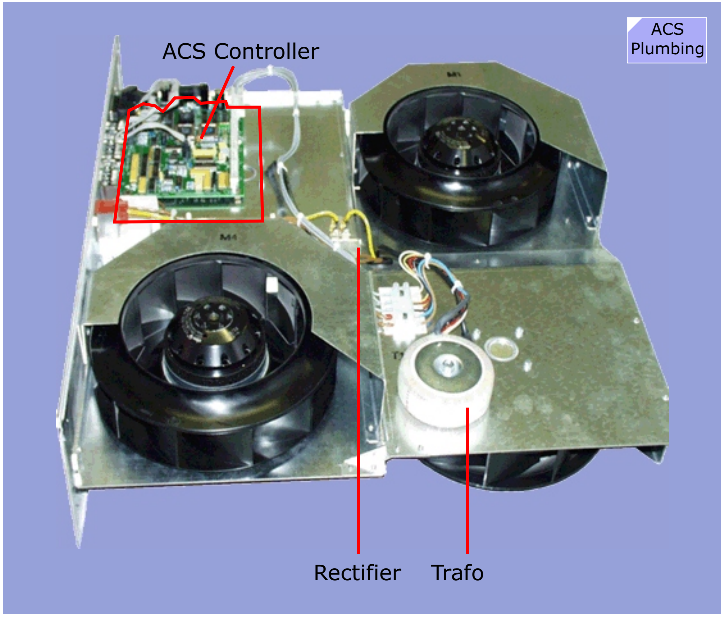
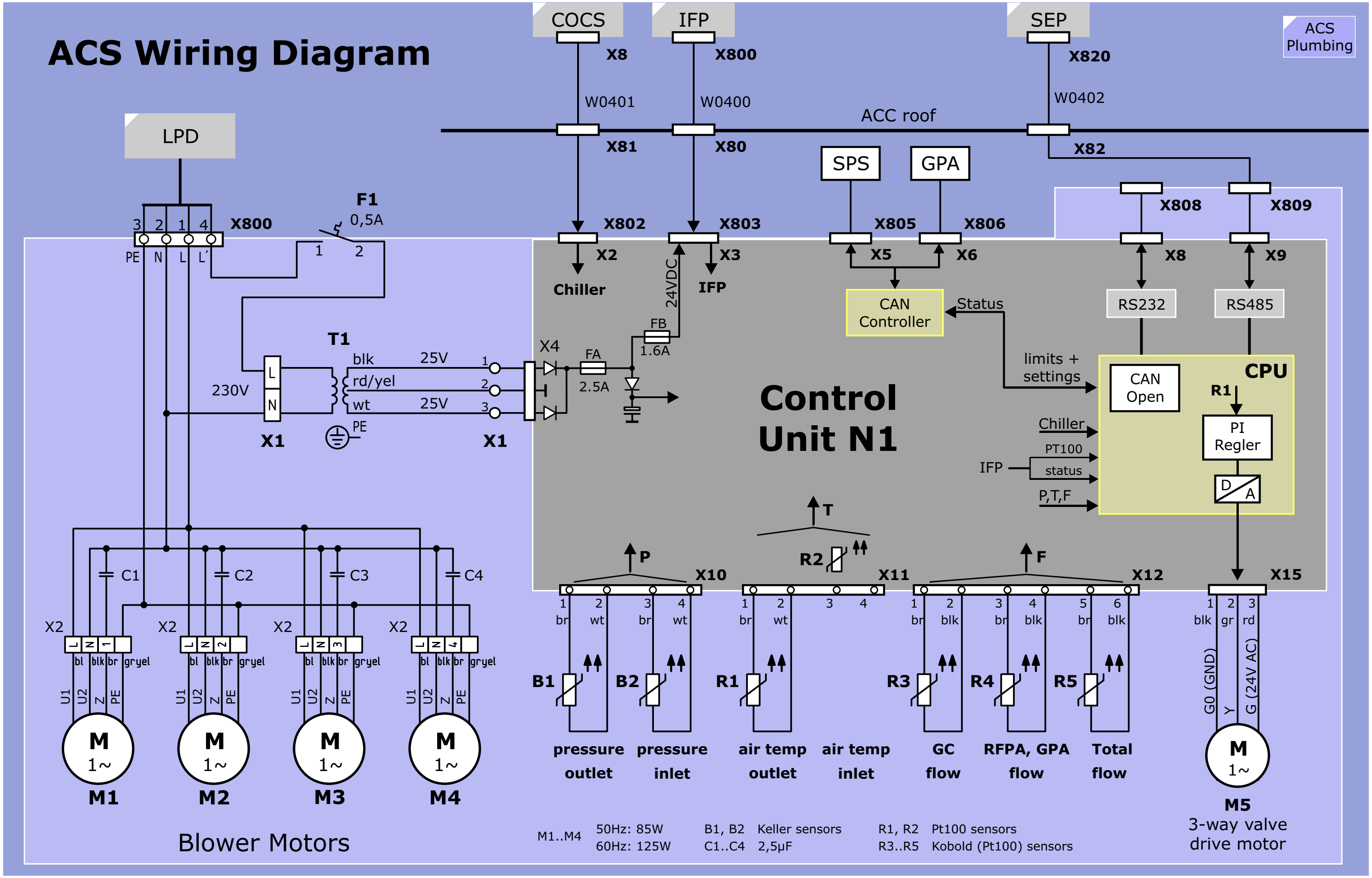


Figure 193 ACS Wiring Diagram



COCS

Overview

The Cost Optimized Chiller System (COCS) and Interface Panel (IFP) supply the 20°C cooling water for the Avanto and provide all components necessary for interfacing to the MR system.

The COCS can be nicely separated into two functional parts:
- Chill Water circuit
- Refrigerant circuit

Chill Water Circuit

The chill water circuit consists of the components found in Figure 194. The main component is the pump. Several sensors and indicators are provided for regulation of the water temperature and monitoring. The input and output temperatures as well as the flow are monitored. Values lying outside of preset limits result in error messages.

Refrigerant Circuit

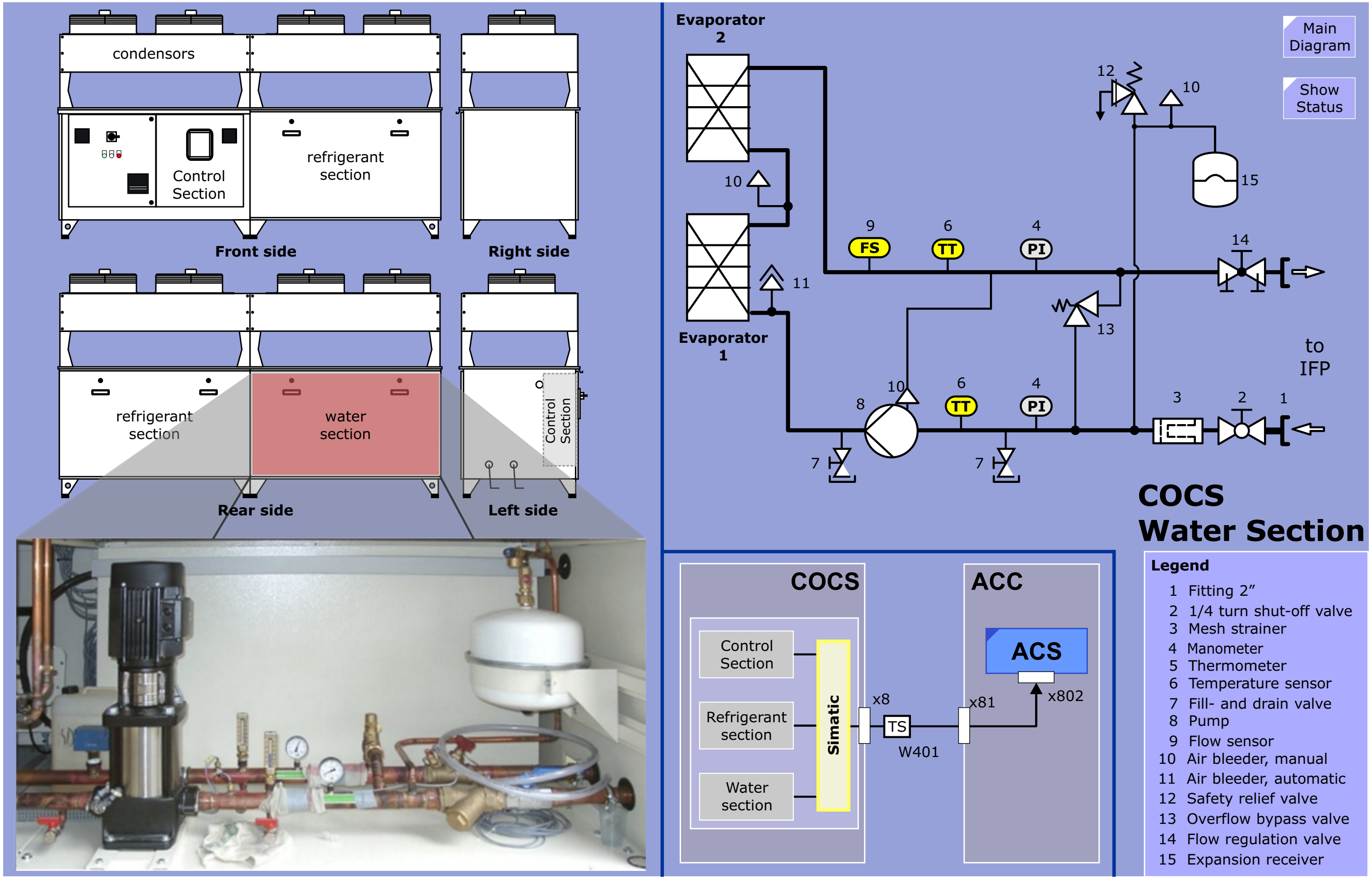
The Refrigerant side of the COCS can only be serviced by external service personnel. Refer to the Planning Guide for a list of service providers in your country.

Status Messages

The chiller monitoring supplies error signals and error messages which differentiate between water and refrigerant circuit errors. There are a total of 3 discrete hardware signals and up to 32 (5-bit BCD-coded) software error messages. The ACS controller is responsible for decoding the COCS messages and passing them on to the MPCU via its CAN interface. Refer to the table below.

Message	Explanation
Hardware Status Signals	
Chiller	Chiller is not ok
Water Circuit	Problem with electrical or water circuit of the chiller
Refrigerant Circuit	Problem with refrigerant circuit of the chiller
Error/Status Messages (5-bit BCD coded)	
see TSG for listing of messages	

Figure 194 *COCS Water Circuit Diagram*



Interface Panel (IFP)

Overview

Serves as an interface to provide a water bypass in the event the cooling water delivered from the chiller falls below 16°C (condensation danger) and several values to isolate the MR system from the Chiller for servicing purposes.

Lastly, a tap for the cooling water to the compressor of the Magnet's Refrigerator System.

Water Bypass

A JUMO Thermometer Controller measures the temperature of the cooling water coming from the COCS, which is located outdoors. In the event the temperature of the incoming water falls below 16°C, the JUMO controller closes **valve 5** and opens the bypass **valve 4**. This action prevents cold water reaching the ACS and system components which would result in condense water in the power electronics and cause a *k a b o o m*.

A status signal, **System_Bypass**, is sent to the CAN SLIO of the ACS via cable W0400 if this event occurs resulting in any running sequences to be aborted.

As soon as the water rises above 16°C the JUMO will reverse the valve settings and reset the System_Bypass signal to the ACS that it is no longer in bypass mode.

MREF Flow Monitoring

A PT100 temp/flow sensor is inserted in the MREF water supply path. The sensor output is not evaluated by the JUMO controller, but is sent to the ACS Control Unit N1 and evaluated there.

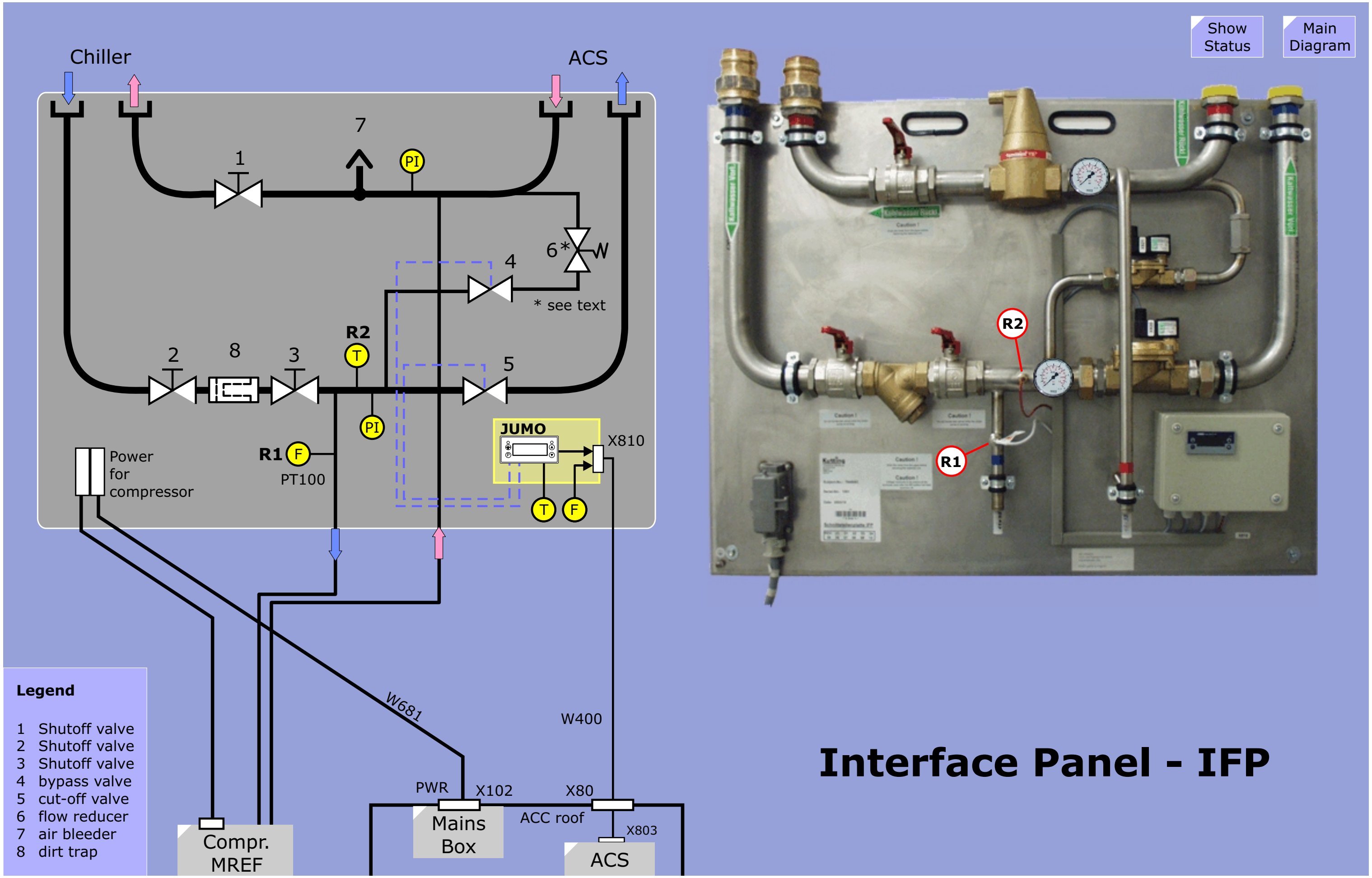
Plumbing Components

- Valves **1** and **2** decouple chiller from system.
- Valves **2** and **3** allow dirt trap (**8**) to be cleaned. (Where is this dirt coming from in an enclosed water system? Beats me...)
- Automatic air bleeder (**7**) lets the air out. Automatically.
- Flow reducer (**6**) reduces the flow. See note below.

NOTE IFPs delivered from August 2005 onwards are additionally equipped with 2 pressure gauges for verifying water pressures on the supply and return sides.

NOTE For IFPs with serial number 1312 onwards delivered with Avanto and Espree systems from January 2006 will have the rev level 02. These IFP panels no longer have a flow reducer but an aperture plate (basically a washer with a "calibrated" center hole size) to reduce the bypass flow. The change was implemented to reduce the peak inlet pressure to under 6,5 bar.

Figure 195 *Interface Panel*



SEP (Separator)

Overview

The Separator (SEP) cabinet is a required when using a chiller which provides chilled water at temperatures between 6 and 12°C.

The SEP fulfills two functions:

- heat exchange of 6-12°C primary to 20°C secondary
- provide separation and protection of MR System from chiller

Specifications

Specification	Value
Primary	
min. flow in primary circuit	90 l/min.
temperature bandwidth	6-12°C
maximal pressure difference	1.5 bar
Secondary	
nominal temp	20°C
temperature bandwidth (temp may leave this bandwidth for maximum 30 sec.)	19-22°C
alarm temp	≤15 or ≥26
max pressure difference	3.5 bar
Flow	140 l/min.

Water Circuit

Function

In case of a power failure the SEP must turn itself on again automatically.

Two **pressure gauges** placed at pump intake (5a) and pump output (5b) are supplied for refilling and troubleshooting.

The static fill pressure (= pump off) is approximately 0.5 - 1.0 bar.

Older systems with a built-in low-pressure switch require a slightly higher fill pressure of 1.5 - 2.0 bar. For the dynamic pressure (= pump on), the pressure difference between both gauges should read 3.5 bar + 0 / - 0.5 bar. Example: Pin = 0.5 bar, therefore Pout must be 3.5 - 4.0 bar (dynamic).

A **safety valve** (16) with a water run-off hose at pump intake is set for 3 bar over-pressure. This prevents the SEP from over-filling.

The **bypass valve** (11) adjusts the pressure difference to 3.5 bar + 0 / - 0.5 bar and prevents over-pressure on MR system components.

The regulation maintains the water temp ≤2K/5min with a running integrations time of 30 s.

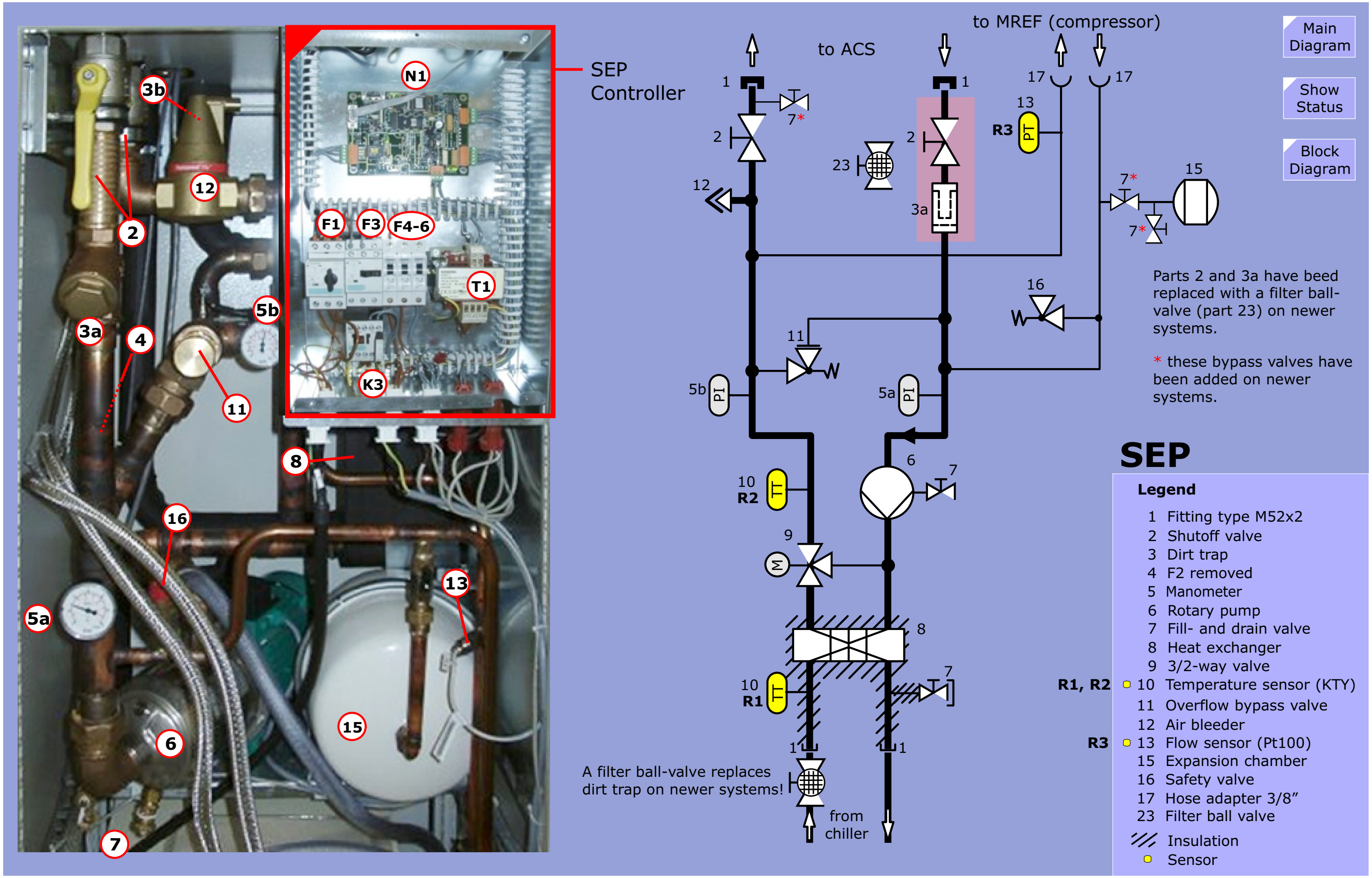
In the event the SEP were to shut off, the compressor will also be disabled. This is achieved with a switch tied into the compressor's control input (see page 254).

On systems delivered after May 2011 this circuit has been removed.

SEP Controller Parameters

Description	Type	Variable
Regulator parameters:		
Kp (P)	analog	yes
Tn (I)	analog	yes
Temp Limits:		
upper	analog	yes
lower	analog	yes
Actual value	analog	no
Status:		
Pump on	digital	no
Service switch on	digital	no
Errors:		
Actual out of tolerance	digital	no
Dry run protection	digital	no
MREF flow	digital	no
Actual primary water temp	analog	no

Figure 196 *Separator Layout*



Electrical Circuit

Overview

The **Control Unit N1** reads in the analog temperature and pressure sensor values and evaluates them against limits which are sent to it via the MPCU-CAN-ACS. The limits are entered into the SeSo/Magnet and Cooling/Alarm Settings mask.

The values which are read out of the SEP controller and displayed in the Magnet and Cooling / Status page are as follows:

Status	Signal type	Value
Pump	digital	OK/Not OK
Pump overload	digital	OK/Not OK
Service switch	digital	OK/Not OK
Primary water temperature	analog	in °C
Secondary water temperature	analog	in °C
Secondary water set point	digital	in °C
MREF flow (under ACS section)	digital	OK/Not OK

Function

Circuit breaker **F1** supplies the MREF (compressor) with AC power. If it trips, a signal is sent to the controller via contact pins F1.11 and F1.14.

Circuit breaker **F3** supplies the SEP water pump. If it trips it sends a signal back to the controller via contact pins F3.11 and F3.14.

Relay **K3** is used to disable the pump if:

- the primary temperature drops below 5°C or rises above 25°C (**R1**). This will prevent pumping too cold or too warm water into the system components
- the water pressure drops below 1.5 bar (**F2**). This is too save the pump motor from burning out from a no-load situation.

In the event of a power failure, K3 will drop out turning off the Cold Head compressor. As soon as power recovers K3 will close and the compressor will automatically restart after 2 minutes.

Pressure switch **F2** signals the controller that there is insufficient water for the pump (dry run protection).

R1 is a KTY sensor measuring the primary water temperature. Software limits are set in the SeSo Magnet and Cooling mask and currently set to 5°C and 25°C.

R2 is a KTY sensor measuring the actual secondary water temperature and is used for the heat exchange regulation.

R3 is a PT100 temp/flow sensor indicating the water flow of the secondary. The value is read out by the MSUP and evaluated for limits.

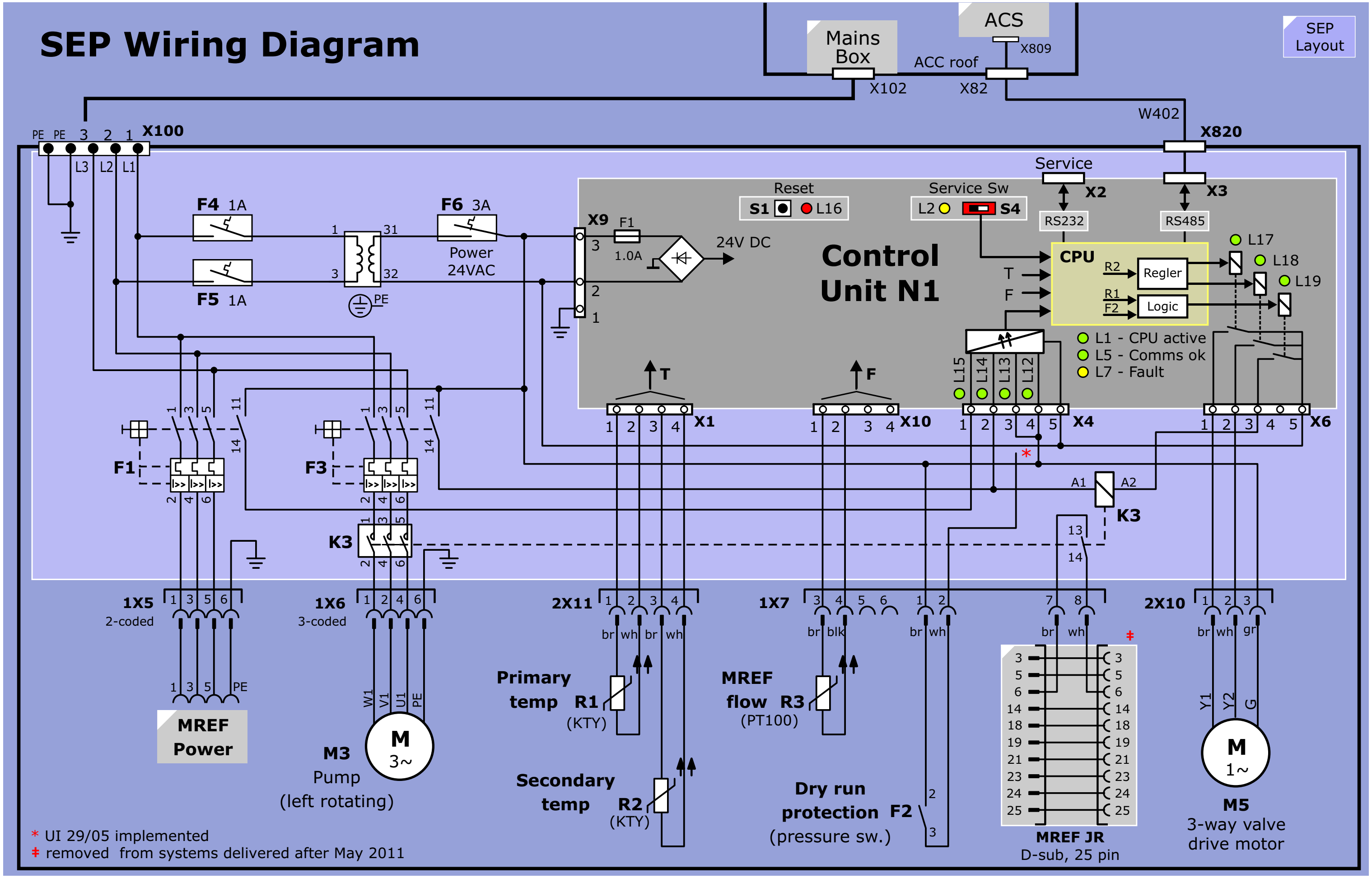
M5 drives the 3-way valve and is controlled by the Control Unit N1 via two on-board relays. The drive action in displayed by LEDs L17 (make secondary colder) and L18 (make secondary less colder).

The status is passed on to the ACS over an RS485 serial interface and from there over the CAN bus to the MPCU.

LEDs

LED	Description	normal condition
L1	CPU active	blink
L2	service mode	off
L5	comms ok	on
L7	fault	off
L12	24V AC present	on
L13	same as L12	on
L14	Pump overload (F3)	on
L15	MREF overload (F1)	on
L16	reset	off (goes on shortly when reset button S1 pressed)
L17	mix colder	on when regulating
L18	mix warmer	on when regulating
L19	pump enable (K3 enable)	on

Figure 197 *Separator Wiring Diagram*



PT 100 Sensor

Principle

The PT100 temperature/flow sensor is an industry standard sensor which uses platinum (thus the name PT) as the thermo-element. Its characteristic is as an PTC resistance: resistance decreases as temperature decreases. The PT100's temp/resistance characteristic is very linear and thus used as an accurate temperature sensor.

To use it as a flow sensor the thermal element is actively heated by running a constant current through it and its voltage is measured. The current heats the elements up, whereby the water flow cools it back down. The voltage is indicative of the elements resistance which is proportional to the elements temperature which in turn is proportional top the flow of water over its housing (the element is not directly in the flow of water). By setting the current the sensor can be used to measure a wide range of flows.

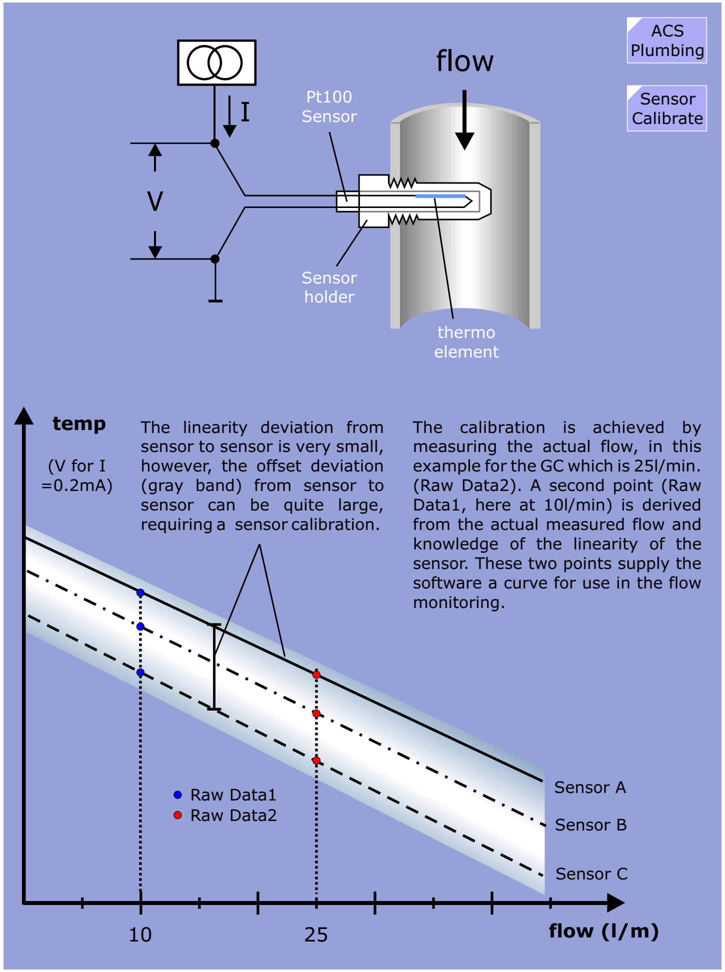
Flow Monitoring

For flow monitoring purposes, the voltage (element resistance) must be known which corresponds to the desired water flow. Although the temp/flow relationship is quite linear and does not deviate much from sensor to sensor, the actual resistance value can deviate from sensor to sensor dramatically. Therefore it is necessary to "calibrate" the sensor by reading its resistance (voltage drop) under operating conditions with the desired flow. Once the sensor resistance has been sampled the value is then used as the monitoring reference. This sensor "calibration" can be performed in the Service Software under Magnet and Cooling.

KTY Sensor

THis sensor uses a semi-conductor as thermo element. Principle of operation is nearly the same as for the PT100, is not as linear however and therefore costs less.

Figure 198 *PT100 Sensor*



Sensor Calibration

The flow sensors must be calibrated during the system installation in order to determine the monitoring limits. During the calibration procedure, it is important that the water pump in the SEP or COCS is running and the main water flow in the case of the COCS has been set to the specifications (see Planning Guide).

NOTE If the sensor calibration is performed when there is no water flow, the water flow monitoring will never recognize a deficient water flow!

Figure 199 *ACS Sensor Calibration*

Calibration of Flow Sensors

- ◉ Sensor GC
- ○ Sensor Supply (GPA, RFPA)
- ○ Sensor Return (GC, GPA, RFPA, ACS)
- ○ Sensor Mref

VB11 software. **Calibrate**

Calibration of Flow Sensors

	Raw Data1	Flow 1 l/10min	Raw Data2	Flow 2 l/10min
◉ Sensor GC	1263	100	1179	250
○ Sensor Supply (GPA, RFPA)	1125	300	1042	700
○ Sensor Return (GC, GPA, RFPA, ACS)	1090	600	1052	1200
○ Sensor Mref	982	50	957	100

≥ VB13 software. **Calibrate**

Monitoring

The Cooling System status masks (under SeSo > Magnet & Cooling) are given below with the corresponding sensors.

Figure 200 *Cooling Status Masks*

Cabinet	Air Temperature Supply		ACS R1	**25.9°C**
	Air Temperature Return		ACS R2	**28.7°C**
	Air Temperature RFIS			**25.0°C**

ACS	Water Temperature Cabinet			**OK**
	Water Pressure Supply		ACS B2	**4.5bar**
	Water Pressure Return		ACS B1	**1.6bar**
	Water Flow GC		ACS R3	**OK**
	Water Flow Cabinet		ACS R4	**OK**
	Water Flow Total		ACS R5	**OK**
	Water Flow Mref	IFP R1	SEP R3	**OK**

SEP	Pump		**OK**
	Pump Overload	F3	**OK**
	Service Switch		**OK**
	Water Temperature (primary)	R1	**12.1°C**
	Water Temperature (secondary)	R2	**20.0°C**
	Water (secondary) set point		**20.0°C**

Chiller	Chiller	**OK**
	Water Circuit	**OK**
	Refrigerant Circuit	**OK**

IFP	IFP	**OK**

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Section

10 Line Power Distribution

Introduction

The LPD has the monumental task of distributing the lines power to the various components within the system. You will find on the next pages schematics of the LPD. Please also refer to the Diagrams document where newer versions may be forthcoming.

Diagrams

The LPD diagrams are found on the following pages. They deviate from the diagrams found in the Diagrams binder in so far that all cable assembly and/or manufacturing remarks have been removed to improve overall readability. Also labelling and signal names have been corrected and/or improved for better signal tracing.

Figure 201 *Line Power Distributor Diagram, Page 1*

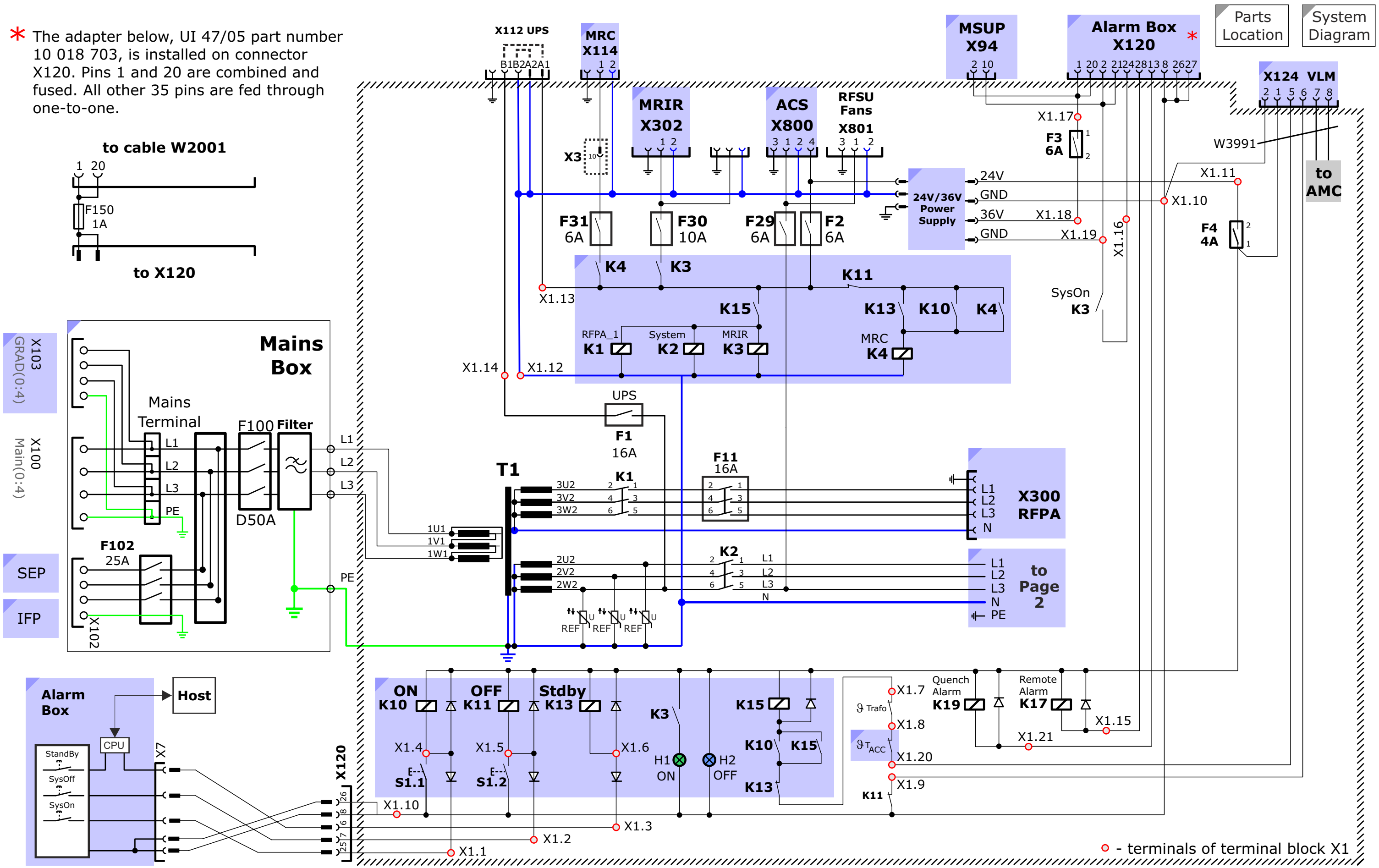
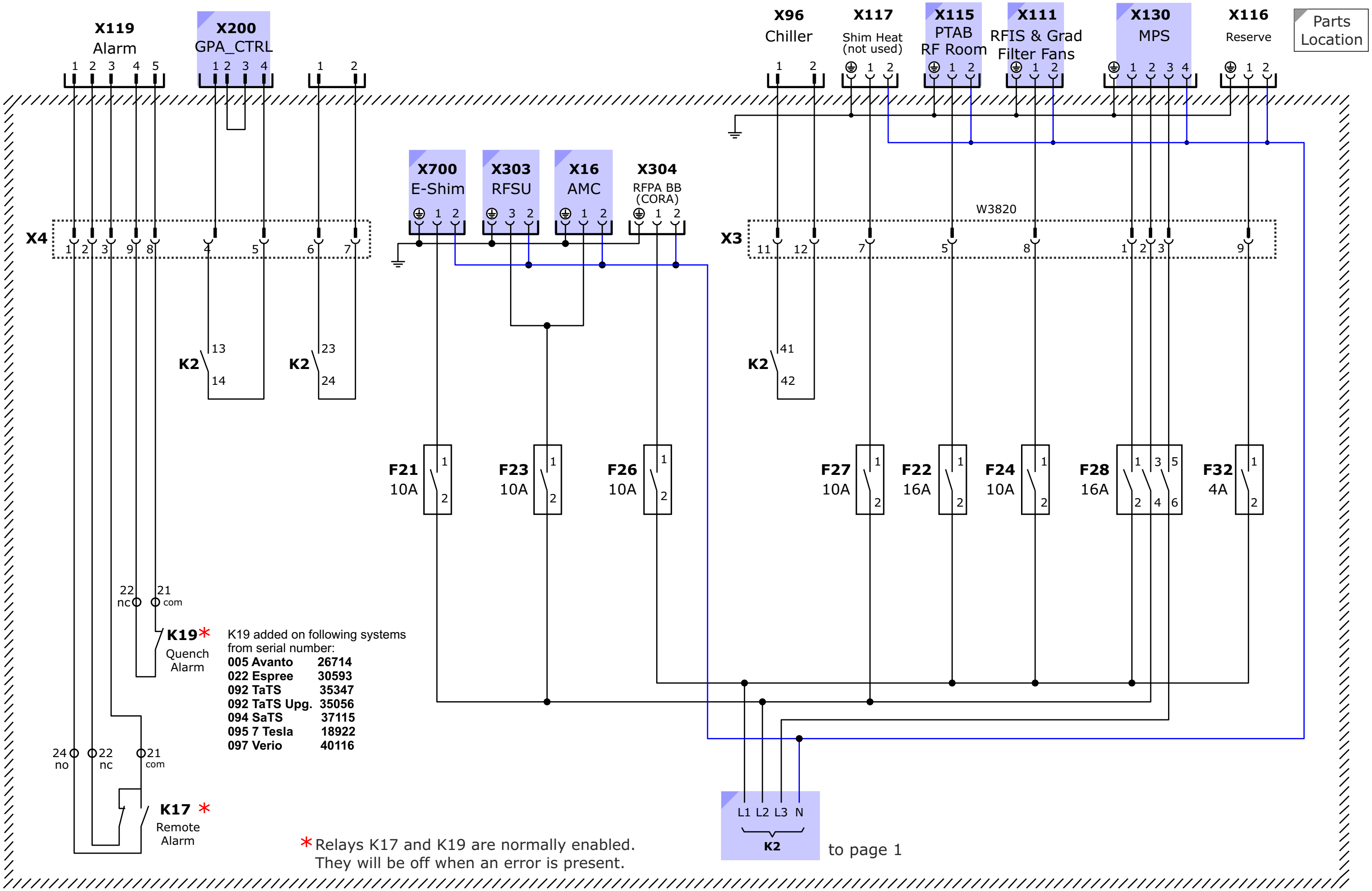


Figure 202 *Line Power Distributor Diagram, Page 2*



Switch Logic

Function

System On

When either the **System On** button on the Alarm Box is depressed or the System On button in the LPD, **K10** is temporarily activated which pulls in **K15** and **K4.** Pins 21 and 24 of relay K15 holds itself on and pins 14 and 11 activate the relays **K1**, **K2** and **K3** which then supply power to the RFPA (K1), MR system components (K2) and the MRIR (K3). **K4** supplies power to the host over pins 1 and 2 and keeps itself on via pins 13 and 14.

System Off

By depressing the **System Off** buttons on the Alarm Box or LPD, **K11** is temporarily activated which deactivates **K15** via contact pins 21 and 22. With **K15** deactivated, relays **K1**, **K2**, **K3** are deactivated removing power to these components. Pins 11 and 12 of K11 also deactivates K4 which removes power from the host.

System Standby

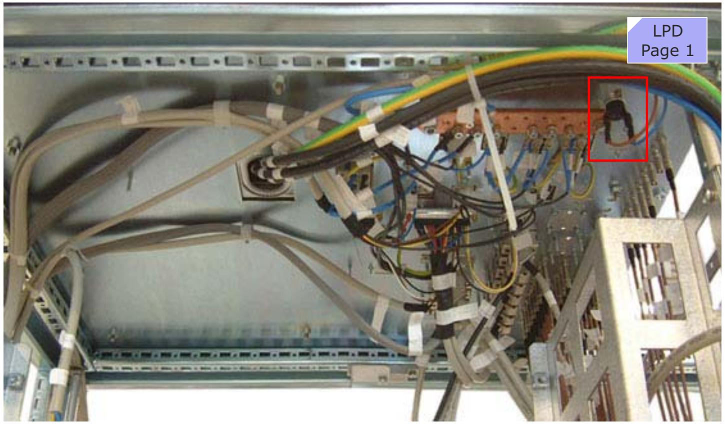
Depressing the System Standby button on the Alarm Box sends a signal to the CPU of the Alarm Box which then sends a message to the host over a serial communication line. The host responds by sending a command to the MRIR to shut down. As soon as the MRIR has shut down, the host sends a command back to the Alarm Box to active the Standby signal to relay **K13**. When **K13** activates, pins 11 and 12 open to deactivate **K15** which in turn deactivates **K1**, **K2** and **K3** removing power from all system components except the host.

The contact pins 21 and 24 of **K13** are not used. It was originally intended to be able to put the system directly into Standby if the system is off.

Overtemp Fail-safe Switches

Tacc and Ttrafo are thermal switches which open when the temperature exceeds 50°C and 60°C respectively. The location of the Tacc switch is at the back left-hand side of the ACC cabinet roof.

Figure 203 *Tacc Temperature Switch Location*



View from rear of ACC Cabinet. From the front side, the over-temp switch is at the extreme back left corner of the cabinet.

Switching OFF and ON individual components.

If you want to turn OFF or ON an individual component then do it in the following way:

- switch the component OFF via SW command
- if available, switch OFF component’s specific circuit breakers
- now switch OFF the component specific circuit breaker at the LPD
- switch ON in the reverse order

Figure 204 *System Power On/Off Switch Logic*

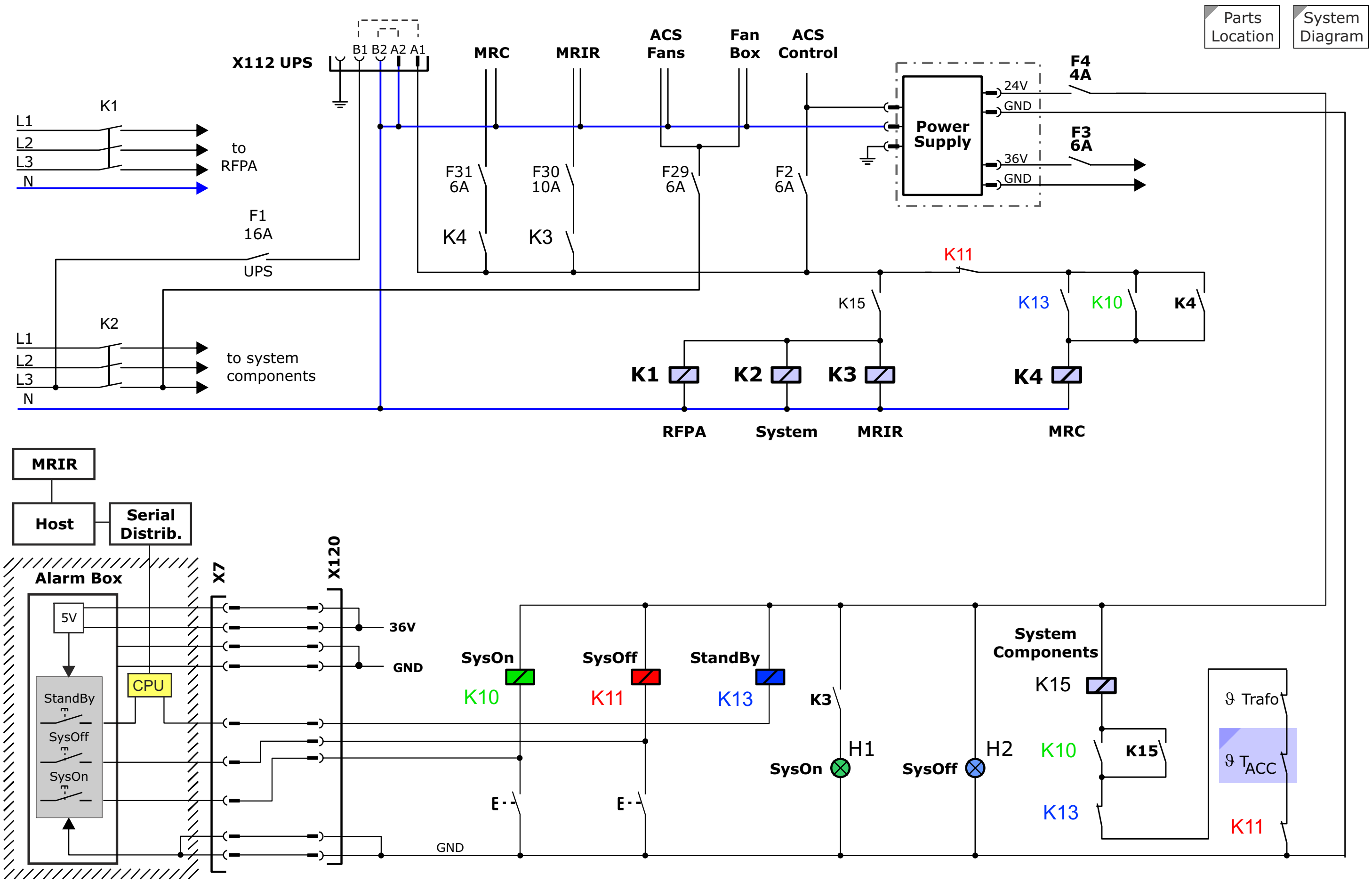


Figure 205 *Line Power Distributor Parts Location*

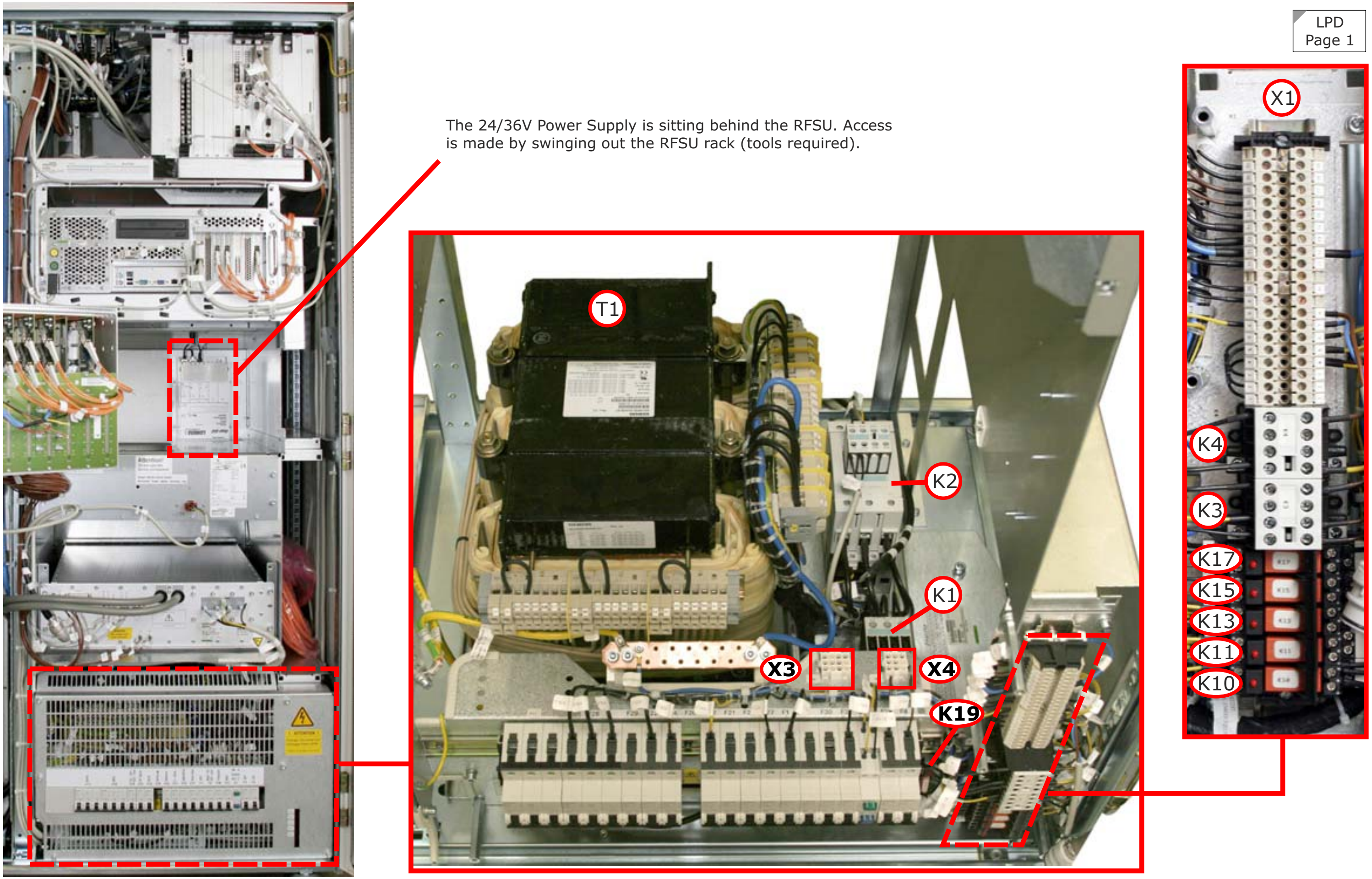
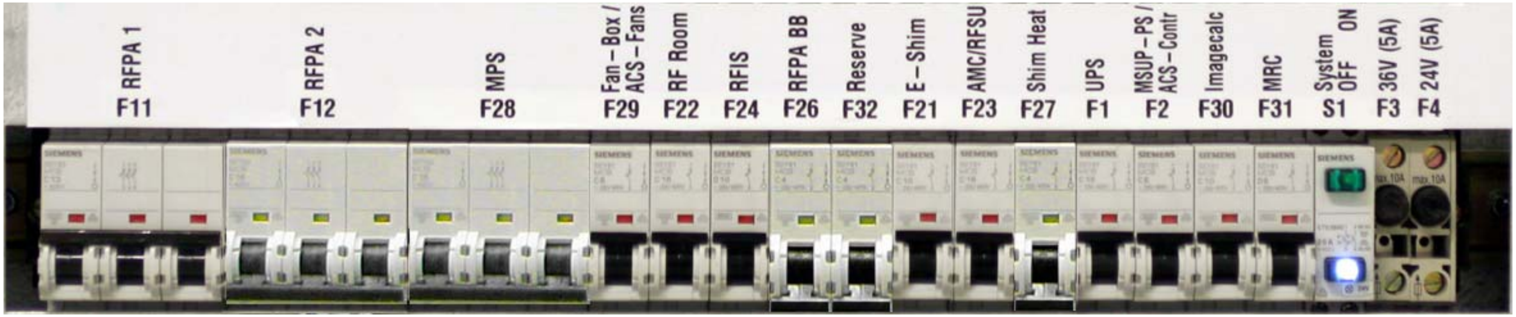


Figure 206 Circuit Break Layout

LPD
Page 2

LPD Circuit Breaker Layout (OLD)



LPD Circuit Breaker Layout (NEW)

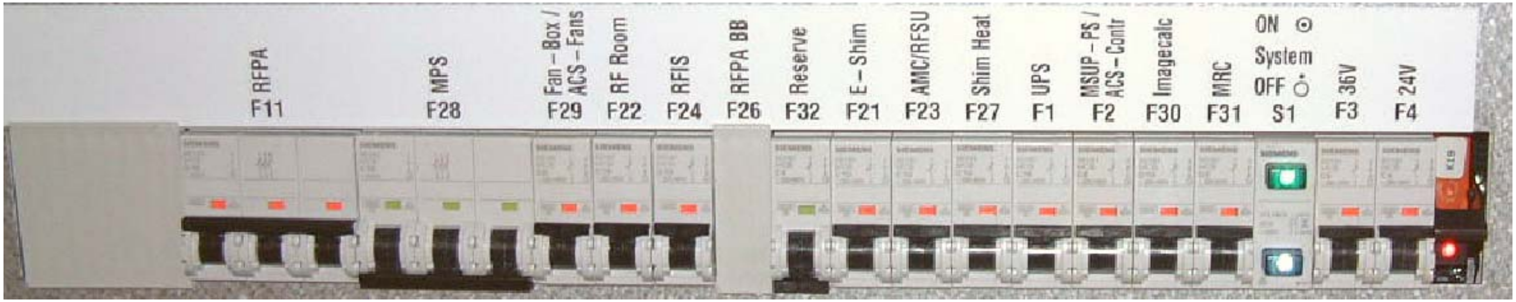
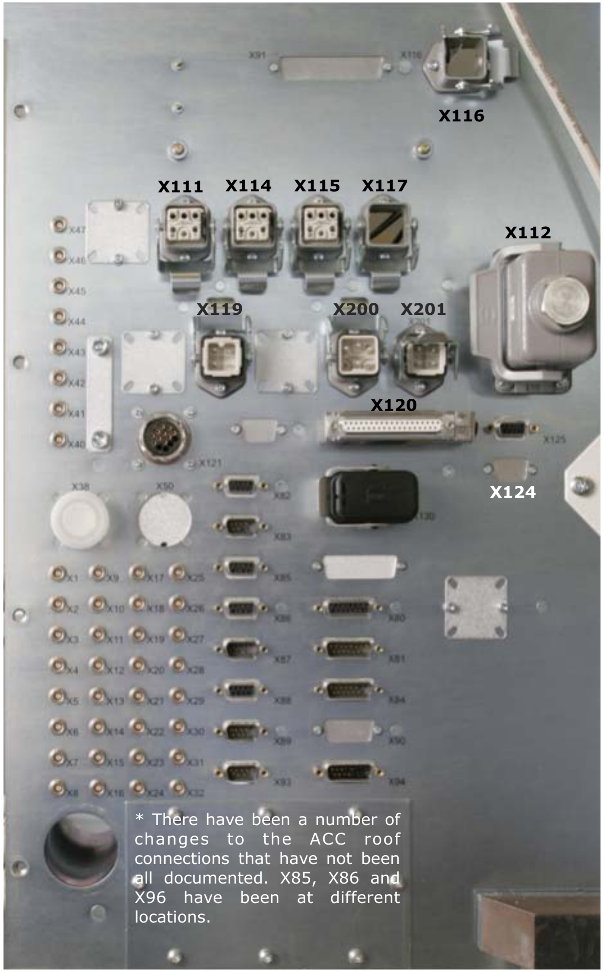


Figure 207 *Mains Box and ACC Roof Connections (Old version)*



* There have been a number of changes to the ACC roof connections that have not been all documented. X85, X86 and X96 have been at different locations.

LPD Page 1

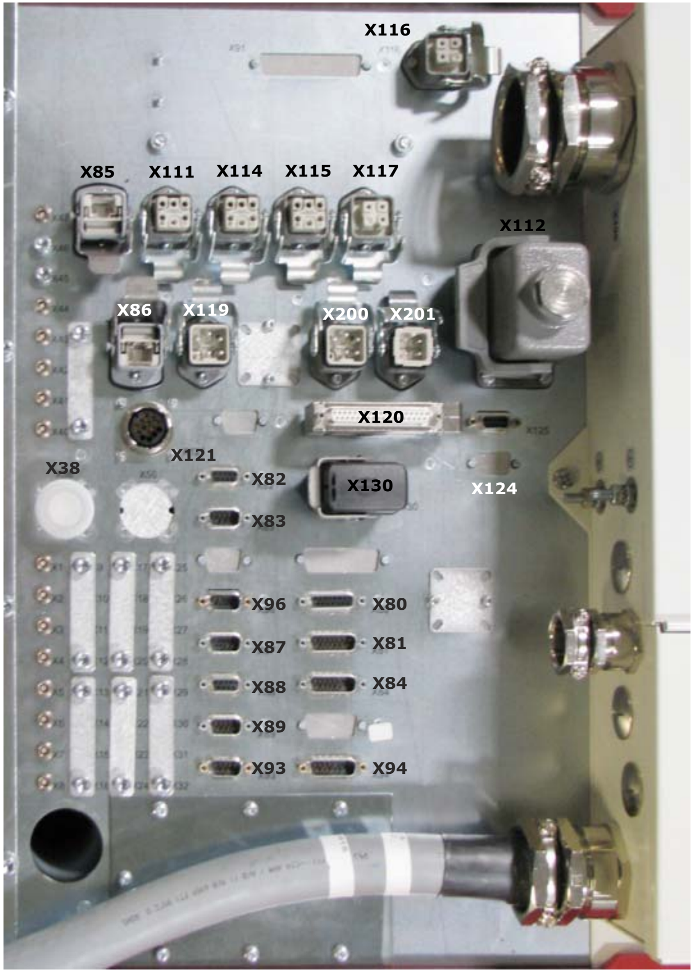
NEW Version

ACC Roof connections

X38	Transmit cable (DORA)
X40	BC pick up (when fitted)
X41	BC pick up (when fitted)
X42	TTX (to RCCS)
X43	CV (from TALES)
X44	CV_0V (from TALES)
X47	PD (from TAS)
X50	Transmit cable (CORA spec)
X80	from IFP
X81	from COCS chiller
X82	from SEP
X83	signals from AMC, not used
X84	from Gradient Filter (fans)
X85	MPCU ethernet (to switch)
X86	MRIR ethernet (to switch)
X87	RF room Door switch
X88	PMU beep to Intercom
X89	Gradient Supervision
X93	from Compressor (status & reset)
X94	to/from MSUP
X96	Chiller contact
X100	Mains input
X101	nc
X102	3p power to SEP
X103	3p power to GPA
X104	nc
X105	nc
X111	1p power to RFIS power supply
X112	1p power to/from UPS
X114	1p power to MRC
X115	1p power to PTAB
X116	1p power (reserve)
X117	1p power (reserve)
X119	remote/quench alarm (for customer)
X120	to/from Alarm Box
X121	E Shim output (to Grad coil)
X124	Gradient Supervision
X125	CAN to MPS
X126	CAN to MSUP
X130	3p power to MPS
X200	power switching (GPA)
X201	power switching (not used)

Mains Box

Figure 208 *Mains Box and ACC Roof Connections (newer version)**



LPD
Page 1

OLD
Version

ACC Roof connections

X38	Transmit cable (DORA)	X100	Mains input
X40	BC pick up (not fitted)	X101	nc
X41	BC pick up (not fitted)	X102	3p power to SEP
X42	TTX (to RCCS)	X103	3p power to GPA
X43	CV (from TALES)	X104	nc
X44	CV_0V (from TALES)	X105	nc
X47	PD (from TAS)	X111	1p power to RFIS power supply
X50	Transmit cable (CORA spec)	X112	1p power to/from UPS
X80	from IFP	X114	1p power to MRC
X81	from COCS chiller	X115	1p power to PTAB
X82	from SEP	X116	1p power (reserve)
X83	signals from AMC, not used	X117	1p power (reserve)
X84	from Gradient Filter (fans)	X119	remote alarm (for customer)
X85	MPCU ethernet (to switch)	X120	to/from Alarm Box
X86	MRIR ethernet (to switch)	X121	E Shim output (to Grad coil)
X87	RF room Door switch	X124	Gradient Supervision
X88	PMU beep to Intercom	X125	CAN to MPS
X89	Gradient Supervision	X126	CAN to MSUP
X93	from Compressor (status & reset)	X130	3p power to MPS
X94	to/from MSUP	X200	power switching (GPA)
X96	to/from Chiller		

* There have been a number of changes to the ACC roof connections that have not been documented. X85, X86 and X96 have been at different locations.

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Section

11 Tune-Up / QA

Introduction

The Tune-Up is a collection of procedures used to calibrate, compensate and/or determine hardware variables needed to optimize the scanners performance in its environment. The Tune Up (TU) will be initially performed when an MR system is installation but also when components have exchanged during repairs. It is also recommended to performed a TU at regular intervals (at least yearly) to maintain maximal system performance since some system components (particularly DAC and ADC offsets) will drift with time. The replacement of parts will usually require one or more Tune-Up procedures to be performed as well. This information is found in the Replacement of Parts procedures.

The QA offers a set of procedures which are intended to verify that the scanner is operating within specifications and as well as procedures that whose main intention is to help determine the cause of poor system performance.

This description will include physical background information of the individual Tune-Up and QA procedures. The more simplified and automatized the service-software has become, the more important it is to have a good understanding of these procedures and what they are doing.

Tune Up Procedures

The procedures fall into three major parts:

- RF-related Tune-Up Procedures
  - Tuning Calibration
  - Body Coil Tuning
  - RF Characteristic
- Gradient-related Tune-Up Procedures
  - Regulator Adjust
  - Table Adjustment
  - Phantom Shim
  - Cross Term Compensation (CTC)
  - Eddy Current Compensation (ECC)
  - Coil Power Losses (CPL)
    (although not a gradient related procedure, it is performed here because it uses the same phantom as ECC and CTC)
  - Gradient Delay
  - Gradient Sensitivity
- Receive Path-related Tune-Up Procedures
  - Receive Path Calibration (to be done with the Body Coil)

Quality Assurance Procedures

The description for the QA procedures begins on page 322

Modes

Each of the Tune-Up steps can be performed in one of two modes:

- **Normal mode**: this is the mode that has to be used to achieve a status of "Done".
- **Expert Mode**: This mode is intended for troubleshooting only. Procedures which can be run in this mode offer the possibility to change or make individual selections of sub-steps of a procedure. For example, a single gradient axis could be measured alone or certain parameters can be selected, such as the terminations for the tuning calibration. The determined or measured values will also be saved in this mode!

Procedure Status

If a procedure is successful, it will be set to **Done**.

A status of **To Do** will be set if it is a fresh installation or when a procedure having interdependencies was performed retrospectively, For example, if a regulator adjustment is performed, all gradient-related procedures will be set to To Do, even if they were set to Done previously.

Also, if a Tune-Up procedure has changed its status then the procedure(s) in the Quality Assurance menu for the corresponding coil are changed to **To Do.**

The ERROR status is set if a procedure has stopped or aborted due to an error or time-out.

Reports

A report is generated each time one or a set of procedures have been performed and are found under "Reports", "Session History".

Report -> PDF file

Beginning with VB13 it is possible to convert and report into a PDF file.

Active Coil Menu

The Active Coil menu shows the name of the currently selected coil that will be used by the Tune-up procedures. Since the body coil is always connected, it will always be the default selection when the Tune-up platform is opened.

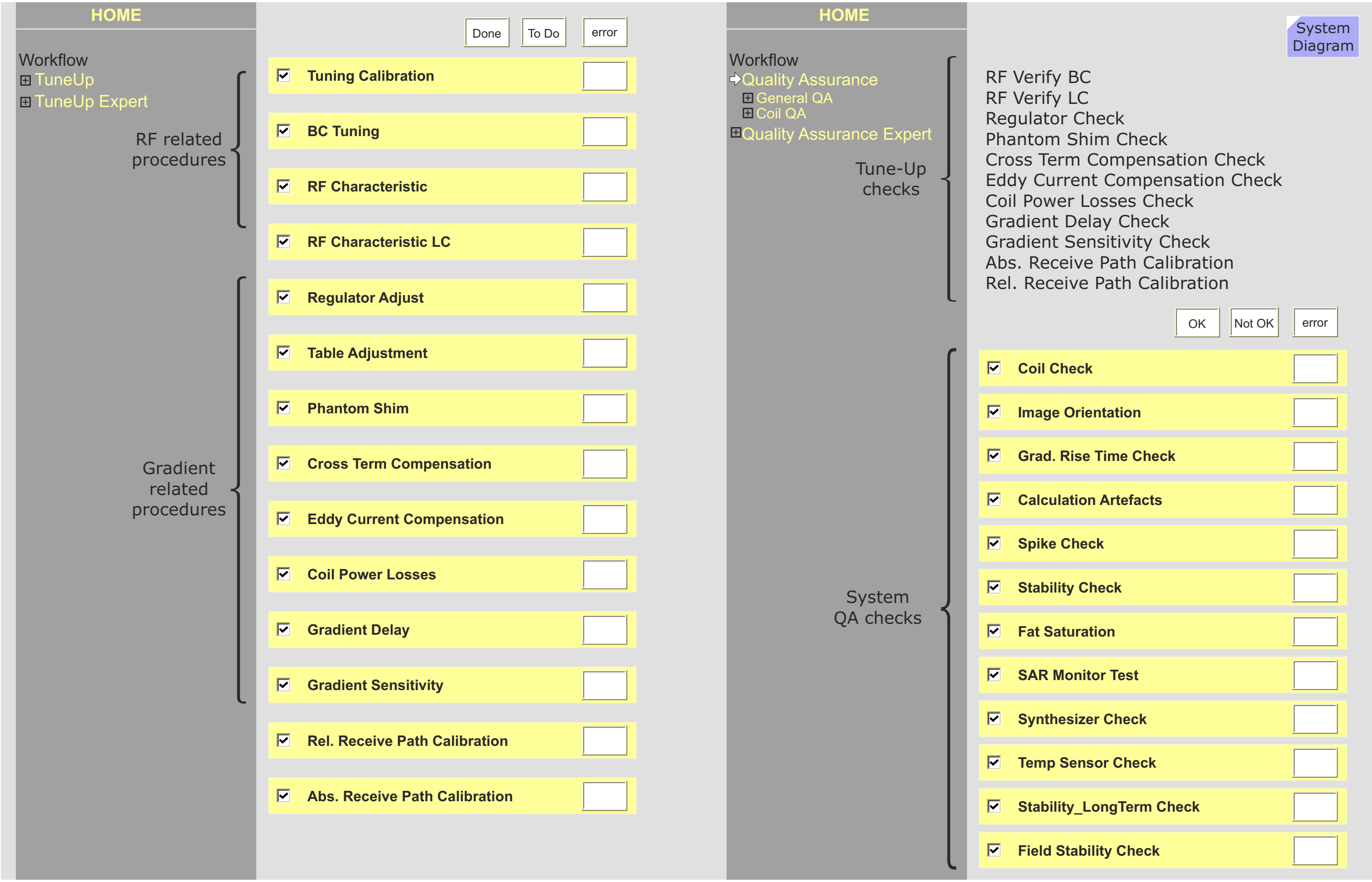
Dependencies

All selected procedures are performed from top to bottom. The individual steps follow a specific order and should not be changed due to the dependencies between those prior and those that follow.

If a Tune-Up procedure has changed its status then the procedure(s) in the Quality Assurance menu for the corresponding coil are changed to To Do.

NOTE	The Tune-Up procedures measure and **SAVE** system parameters. Therefore the Tune-Up procedures should NOT be used for trouble shooting of if the system in not in proper working order. The **Quality Assurance** procedures only measure and **VERIFY** system specifications without saving any system parameter.

Figure 209 *Tune Up and QA Procedural Steps*



RF Related Tune-Up

Tuning Calibration

The circuit used to test the Body Coil (once also used on the Symphony system for Body Coil impedance matching) must first be calibrated before it can be used. The calibration is normalizing the *impedance characteristics* of the components in the Body Coil Measurement Circuit which includes the TX_Module, RX_Module, all connecting cables and the BCCS, RCCS and TALES.

Measurement

The TALES output will be terminated with an open, a short and a 50 ohm termination which covers the complete impedance range. Under these different impedance conditions the forward and reflected values are measured by applying a rectangular RF pulse (tuncal sequence) to the Ur and Uf side of the directional couplers in the BCCS. For each termination condition, the frequency is varied through a range of 63.45 to 63.75 MHz in 10 kHz steps (31 measurements).

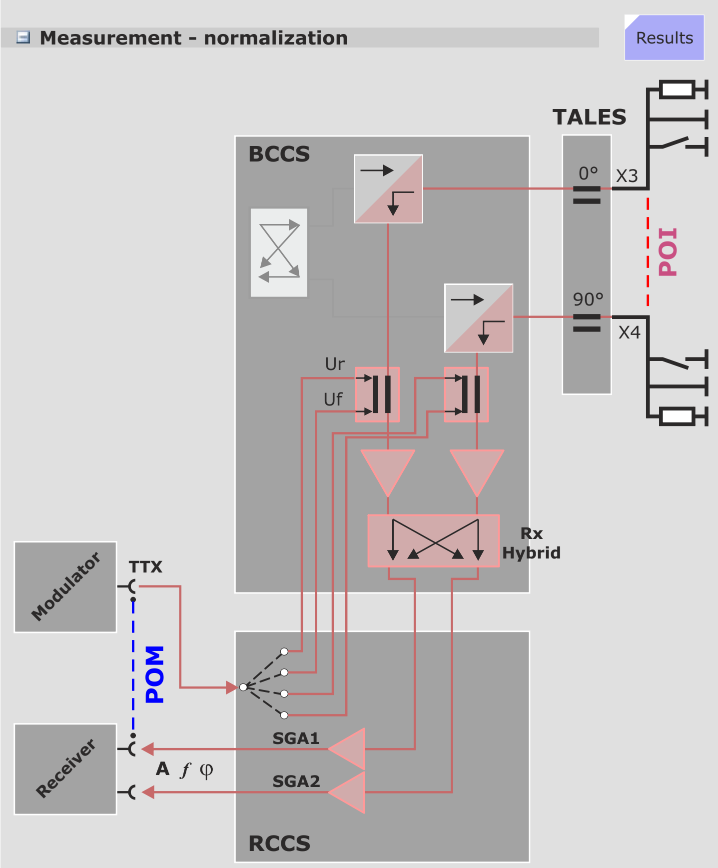
The next measurement is necessary since there is also a coupling of the two Body Coil systems over the Rx Hybrid. This coupling has the result that impedances of the 0° system couple through to the 90° system effecting its impedance and vice versa, so it must be measured and compensated as well. This is done by measuring the 90° path when sending with the 0° and vice versa. The coupling factors are expressed as H-parameters.

After this measurement the Tune Measurement Circuit will be normalized and the point of measurement (POM) (i.e., the point where the system knows the exact amplitude, frequency and phase of the signal being sent or received) will have been transferred to the Point of Interest (POI) and the system is now able to "see" the impedance conditions at the POI.

Expert Mode

Is available, but not useful.

Figure 210 *Normalization of Tune Circuit*



Tuning Calibration - NORMALIZATION:
measuring the effects of the components between the POM and the POI (items in RED)

Results

The graphic displays the results of the H parameter (Rx hybrid coupling). Each colored line represents one of the four measured H parameters with each line displaying the 31 measured frequencies (tick marks).
It is difficult to interpret this graphic since the lines will always be round. You may notice, however, that the blue line begins, for example, at real part 0 and imaginary part of approximately 0.75 and runs to r=0.6/i=0.2. All other lines begin and end at different points. The graphic may be of help if compared with curves measured at a time when the system was functioning properly. Otherwise: forget about it.

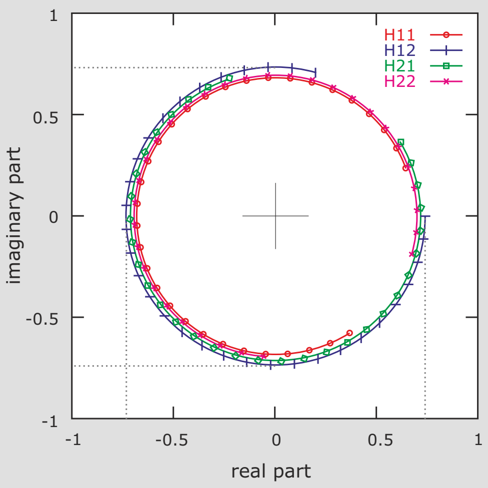
The tuning calibration is also verified. This is accomplished with two measurements. The first measures a 50 ohm termination. on the 0° system. If the tuning calibration measurement was correct, both real and imaginary parts for 50 ohms should be zero (= 0% reflection). The second verification measures a short (0 ohms) on the 90° system which should give a result of real = -1, imaginary = 0 (100% reflection). The results are displayed in the two tables.

Testing the Tuning Calibration

There is a service test in the TestTools under RF system / BTB Interactive that also checks the tuning calibration. This test uses, however, an open termination instead of a short (as used in the measurement described above) which should result with a value of real=1, imag=0 if the last saved tuning calibration is still valid (i.e., nothing in the tuning circuit has changed).

Figure 211 *Results of Normalizations*

Results BACK



TALES Reflection Verification 0-system (50 ohm)

	Value	Low Spec	High Spec
TALES_0_Reflect_Real	0.00	0.00	0.02
TALES_0_Reflect_Imag	0.00	0.00	0.02

TALES Reflection Verification 90-system (short)

	Value	Low Spec	High Spec
TALES_90_Reflect_Real	-1.00	-1.02	-0.98
TALES_90_Reflect_Imag	0.00	0.00	0.02

Body Coil Tuning

This procedure is used to measure and, if necessary, adjust the central *resonant frequency* of each of the two Body Coil systems as well as minimize the *coupling* between them.

This procedure is only possible for systems with the bird-cage Body Coil (BC47-2).

Measurement

The measurements are performed with fixed Cs/Cp values and over an 800 kHz frequency range. The resonant frequency is found at that point where the reflection of the BC has a minimum. The decoupling is given by the frequency where the transmission has its maximum value. The transmission is determined at that frequency where the transmission (coupling) has its maximum value.This should be lower than -16 dB. A -16dB coupling translates into a 2.5% power loss! Therefore, the lower the coupling, the less losses.

Evaluation

Resonant Frequency

The procedure measures the frequency response of the Body Coil over an 800 kHz frequency range. The evaluation determines:

- if the center frequency of each Body Coil system is between 63.45-63.75 MHz
- that the center frequencies of both coil systems are tuned to within 100 kHz of each other
- that the reflection factor is not more than 30% ($r \leq 0.3$)

Transmission (coupling)

The transmission through the Body Coil, that is, the amount of coupling between the two Body Coil systems, describes a mutual inductance between the Body Coil systems due to coil construction. The transmission is measured by sending a signal into the 0°-system and measuring what comes out of the 90°-system.

Adjust Procedure

This is a manual adjustment requiring the rear tunnel cover to be removed. On the Body Coil are three 50-turn trim capacitors (refer to Figure 212 below), two for adjusting the frequency of each Body Coil system and one for minimizing the coupling between the two.

Tuning

The trim capacitors **T1** and **T2** vary the resonance frequency of the system 1 and 2 respectively. These 50-turn capacitors vary the frequency by approximately **5 kHz per turn**. Turning the cap **CW LOWERS** the frequency, **CCW INCREASES** the frequency.

Decoupling

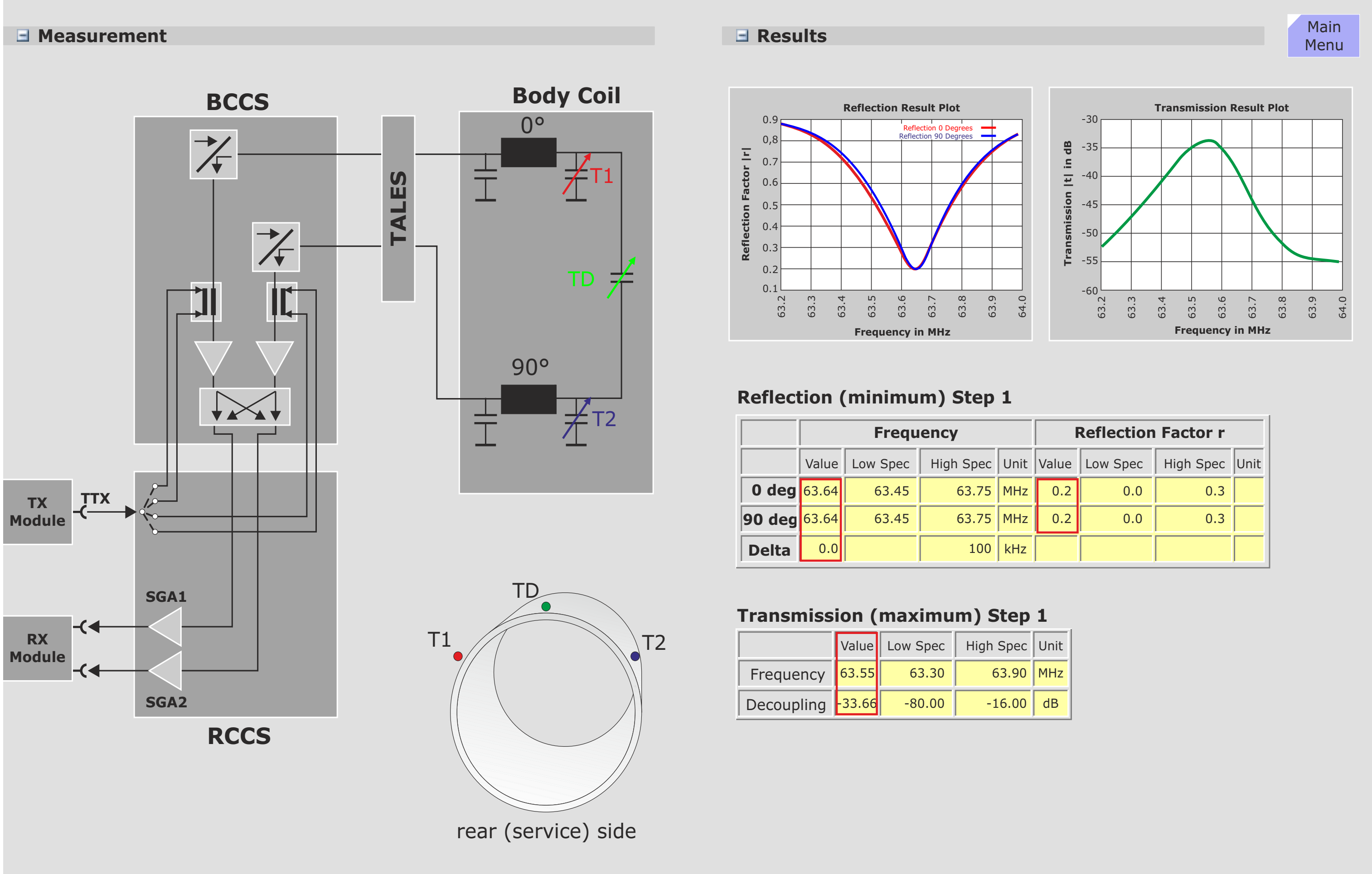
TD is also a 50-turn capacitor and effects the decoupling between the two BC systems. It is not possible to know which direction to take at first, but there is only one minima.

NOTE There is a interdependency between all three adjustments! Refer to the TSG for a detailed description of this procedure.

Expert Mode

There is no Expert Mode for this procedure.

Figure 212 *Body Coil Tuning and Decoupling Adjustments*



RF Characteristic

The calibration of the RF transmitting system is important for obtaining optimum image quality. The RF pulse amplitude defines not only the flip angle, but the pulse lobe amplitude relationship also defines RF pulse profile and hence the slice profile in slice-selection imaging.

Effects of amplitude distortions

Amplitude distortions of the RF envelopes caused by the non-linearity of the amplifier can have the following consequences:

- distortions of the slice profile and slice thickness causing crosstalk between adjacent slices leading to a reduction in signal to noise.
- distortions of the slice profile may also cause partial volume effects resulting in loss of contrast.
- wrong flip angle leading to unwanted contrasts with gradient echo (gre) sequences or loss of S/N in both spin echo (se) and gradient echo sequences

The principle of amplitude corrections is shown in the next graphics

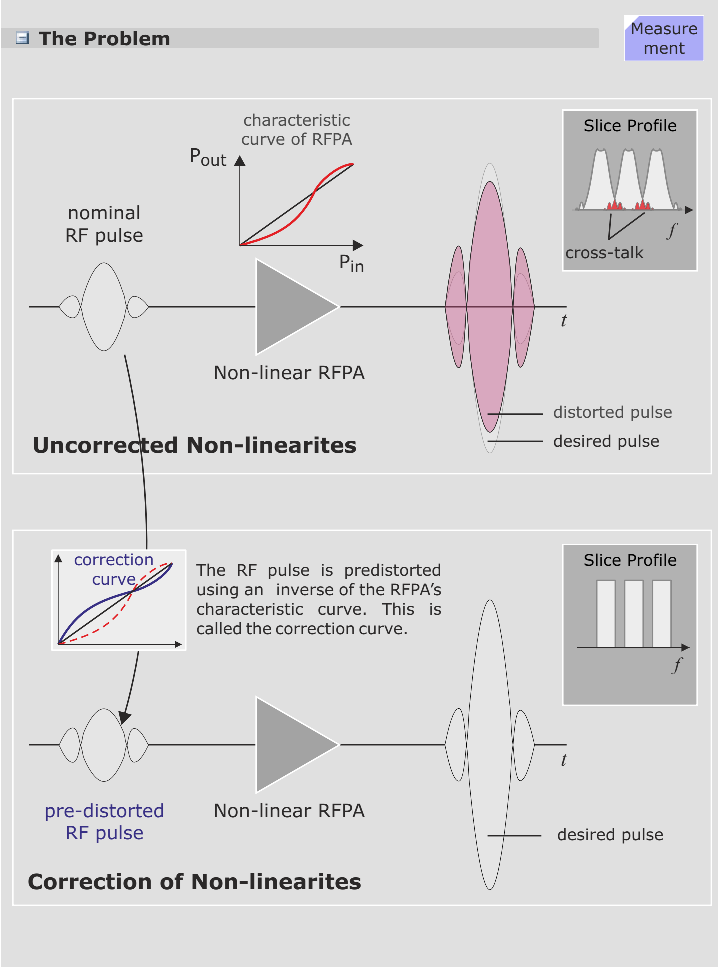
Effects of phase distortions

A phase distortion would lead to a shift or drift in the frequency, which would result in false slice positions hence the phase distortion must also be corrected.

Method of correction

The distortion caused by the non-linearity of the RF amplifier is corrected by measuring the output of the RF transmission in terms of the amplitude and phase based on a known input to the RF amplifier for the entire operating range of the RF amplifier, thereby defining the input/output characteristic of the amplifier. The corresponding inverse function of the amplitude and phase characteristics are used for pre-distortion of the input signal in order to achieve a linear output characteristic and to optimize the RF excitation.

Figure 213 *RFPA Non-linearity*

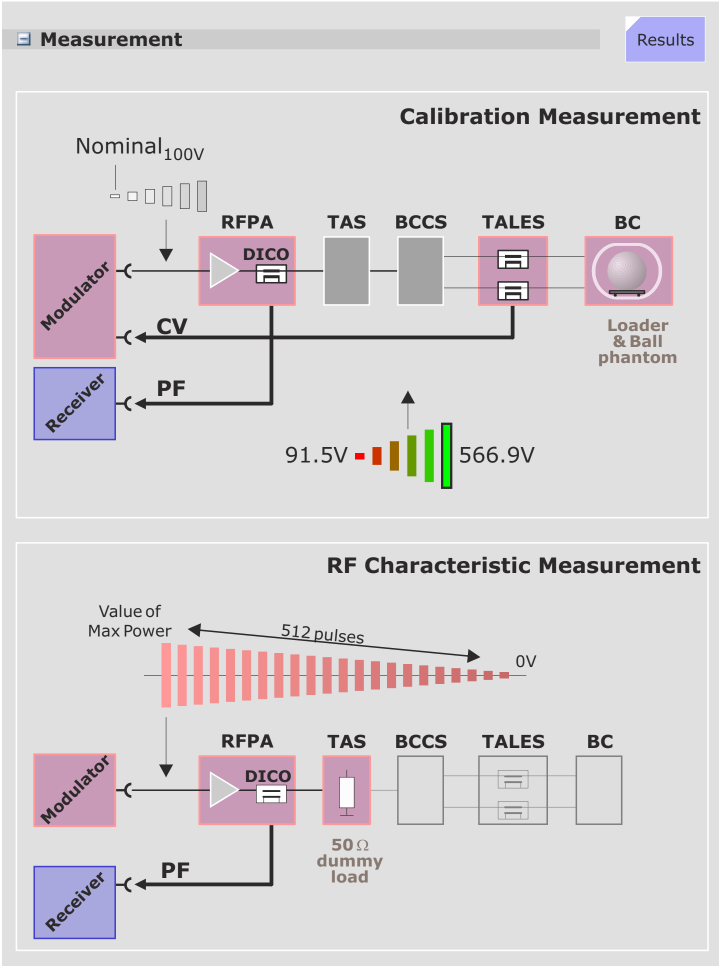


Measurement

The RF-characteristic-measurement is performed with the following steps:

1. **Calibration Voltage Search:** Starting with a nominal value of 100 Volts, the output is increased until a value of 566 Volts is measured at the TALES.
2. **RF Calibration:** The characteristic measurement will be made using the DICO, so it must first be calibrated. Using the results of the first step, the DICO value will also be measured giving a relation between the TALES and DICO. This value is used as a correction factor for the DICO values.
3. **RF Max Power Search:** The system now determines the input voltage to the RFPA required to achieve an output power at the coil of 12.2kW for the DORA RFPA (18.2kW for the PORA RFPA), the power range over which the RFPA will be calibrated. It begins with a nominal value and increments the input until the 12.2 kW (18.2kW) has been reached.
4. **RF Characteristic measurement:** For the following measurement the RF is sent to the 50Ω dummy in the TAS. 512 pulses with different amplitudes are applied. The first pulse starts with the maximum voltage, then the voltage drops by 0.25 dB for each pulse. In this way the complete characteristic is measured.
5. **Save the RF Characteristic** result in the *rfchara.dat* file.
6. **Verify**: The final step is to **perform a verification measurement**. The inverse of the measured characteristic curve is now used to pre-distort the RF pulses. The result should be a linear output transfer characteristic of the RFPA.

Figure 214 *RF Characteristic Measurement*



Results

Plot of Measure Characteristic

The first set of graphics show the measured amplitude and phase characteristic curves each measured with 512 measure points. with a normalized RF input.

Plot of Calculated Characteristics

The second set of graphics displays a calculated version of the measured data mentioned above. The measured data is used to generate an equidistant RF Characteristic correction data base on input amplitude, slope and phase necessary for the RF Characteristic data file. The output data is first made by dividing the maximum voltage into 1024 equidistant points. The corresponding input and phase data is then calculated by interpolating with the actual measured data. Non-unique amplitude data is avoided by simply ignoring this data when generating the input data. Finally, the output data and phase data is converted to slope and phase values.

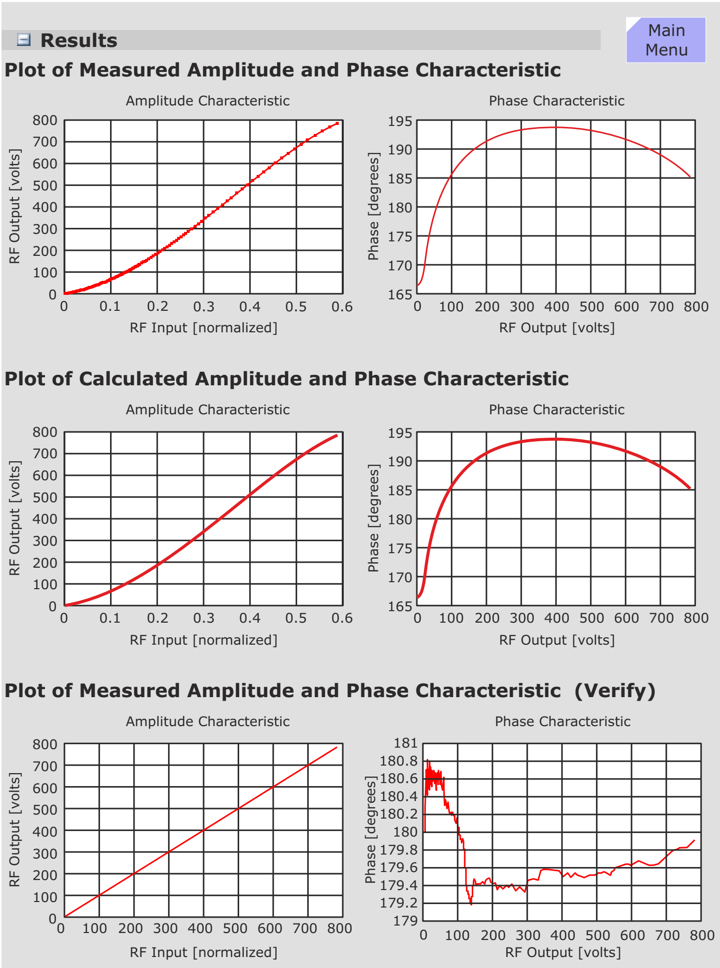
Plot of Verification Measurement

The last set of graphics display the evaluation results of the verification measurement. The verification measurement is made by using the inverted characteristic curve to pre-distort the RF pulses. For a correct compensation, the result should be a linear input to output transfer characteristic. The evaluation is made by calculating the deviation of the measured data to an ideal linear function which is derived by simply creating a straight line between the first data point (0V) and the last data point (maximum voltage). A check for monotony is also made, assuring that the amplifier at no time went into saturation.

Expert Mode

The expert mode allows the user to specify the maximum voltage. The voltage input must be between the range 50% to 100% of MaxPowerAllowed.

Figure 215 *RF Characteristic Results*



RF Characteristic for Local Coils

For systems with multi nucleus spectroscopy option the RF-Characteristic must be measured using all RF-amplifiers and all available nuclei (H and all X-nuclei) in the Local coil (LC) path. An interaction of the service technician is necessary:

Measurement

The dummy load in the TAS_C must be connected to the LC-output of the TALES (i.e. disconnect output cable from TALES X6, disconnect input cable at BCCS X7 and connect it with TALES output X6) and the service plug must be connected to patient table coil plug 1.

The RF characteristic is measured as follows:

1. **Calibration Voltage Search:** Starting with 100 Volts output (this is just a nominal value). The TALES readings are used to increase the output until 250 Volts output are measured.
2. **RF Calibration:** The DICO has to be calibrated since it is used for the final measurement of the characteristic. The DICO value is measured based on the resulting input voltage from step 1. The DICO is calibrated using the known relationship between TALES and DICO.
3. **RF Max Power Search:** By carefully increasing the output voltage, the max. power of 1900 W, respectively 2440 W (depending on nucleus) is searched.
4. **RF Characteristic measurement:** For the following measurement, the RF is sent to the 50Ω dummy in the TAS. 256 pulses with different amplitudes are applied. The first pulse starts with the maximum voltage, decreasing by 0.25 dB for each subsequent pulse. This ensures that the complete characteristic is measured.
5. The **RF Characteristic** is saved in the *rfchara.dat* file.
6. The final step is the **verify measurement**. This includes the calculation of amplitude and phase deviation and checking if the results are within specification. The results and graphics can be viewed in the service software under Tune-Up, Report, Tune-Up Results.

Results

Same as for RF Characteristic procedure for Body Coil.

Expert Mode

In Expert Mode, the function operates similar to standard mode except that the following options are available:

1. You can click **Save** to save the **RF Characteristic** after measurement.
2. You have an option to modify the "Maximum allowed RF power".
3. Selection of RF-amplifier, coil path and nucleus.
4. Option to switch off the frequency adjustment
5. Option to disable switching of TAS to dummy load.

Also, Expert Mode does not include RF-verification at the end of the measurement.

Go back to MAIN MENU

Gradient Related Tune-Up

Regulator Adjust

The regulators in the newest very-high-power Gradient Amplifiers (500A and above at 2000V) have a **proportional**, P, (= gain), **integral**, I, (= time) and **differential**, D, regulation characteristics, thus each regulator consists of a P, I and D regulator circuit in series. The purpose of this procedure is to find the optimal P, I and D regulator adjustment values for an optimized regulation characteristic.

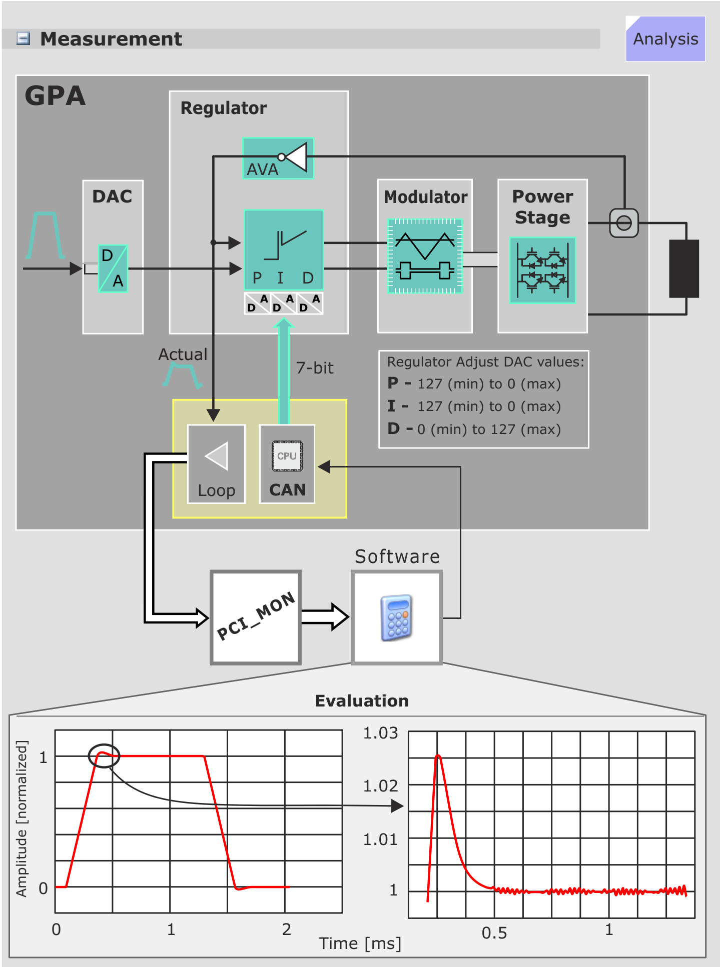
Measurement

The regulators are tuned one after the other in the order PID. Each regulator begins with a configured start value or in Expert Mode with the user given start value. The regulator value is incremented and a measurement is done. The measurement results are evaluated and a new regulator value is calculated. This step is repeated until the regulator is optimized. Finally, a configured *safety factor* is added to the regulator.

The actual value gradient waveform is sent over the gradient loop path from the D16 Service Can board in the GPA to the RX_Module in the RFSU and acquired by the ADC, with 256 sample points. The GradReg program then performs the following:

- checks whether the data is in the real or imaginary part
- displays the measured pulse: the first graphic shows the complete gradient pulse, the second graphic displays the overshoot of the gradient pulse
- performs an evaluation (described below)

Figure 216 *Regulator Adjustment*



Evaluation

The pulse is evaluated for three criteria:

- **Overshoot** amplitude to the nominal pulse amplitude (in %)
- **Decay time** for overshoot to decay to 15% of its amplitude
- **Smoothness** is the maximum positive deviation of the gradient pulse top portion.

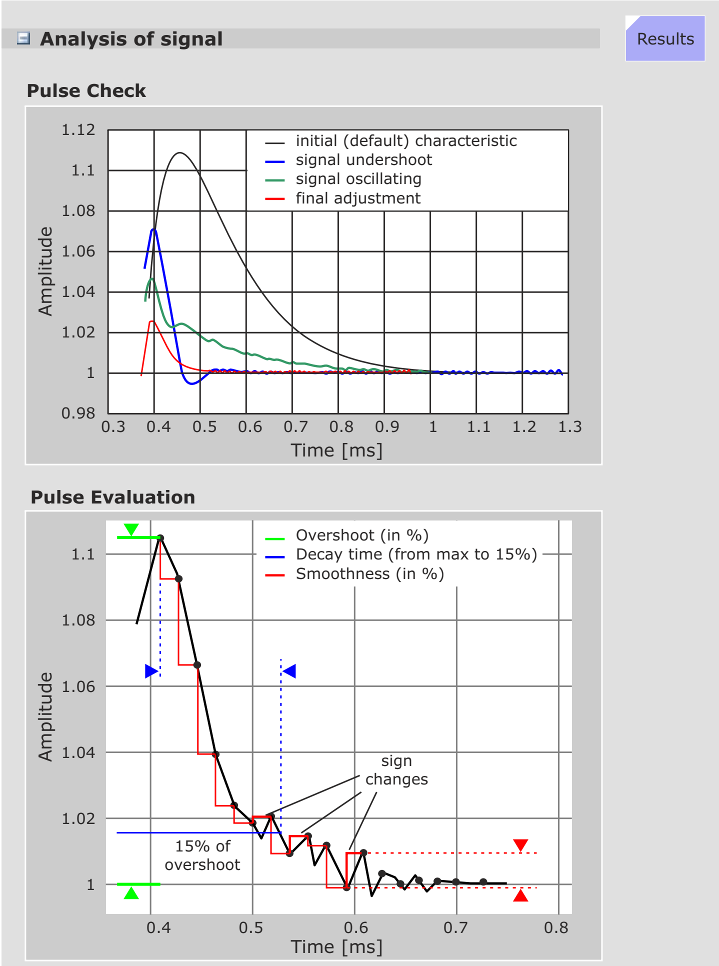
The smoothness of the overshoot is determined in this way: Starting from the maximum data point of the overshoot, the difference to the next successive data point is determined. This is repeated for all data points of the overshoot. The smoothness factor is the maximum difference determined by the above process divided by the nominal pulse amplitude, expressed in %.

Pulse Check

A check if the regulator is being over-driven or the pulse signal oscillates is also made, indicated by 2 or more sign changes in the data points of the overshoot.

If there are points with an amplitude below the nominal amplitude an undershoot after an existing overshoot is detected. That means over-driven regulator or oscillating signal.

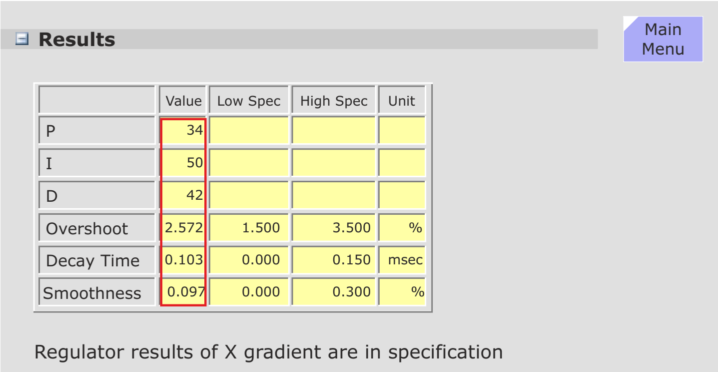
Figure 217 *Regulator Signal Evaluation*



Results

The final regulator adjustment values and achieved values are displayed in tabular form.

Figure 218 *Evaluation Results (final results)*



	Value	Low Spec	High Spec	Unit
P	34			
I	50			
D	42			
Overshoot	2.572	1.500	3.500	%
Decay Time	0.103	0.000	0.150	msec
Smoothness	0.097	0.000	0.300	%

After the regulators have been optimized it is checked if the signal is in specification. If in spec the regulator values are saved permanently. If an error occurs or the program is aborted and the old regulator values will be restored.

Expert Mode

If the factory default values are too tight and cause the regulator to oscillate and result in an aborted measurement, the default values can be changed in the Expert Mode menu.

Figure 219 *Default Settings*

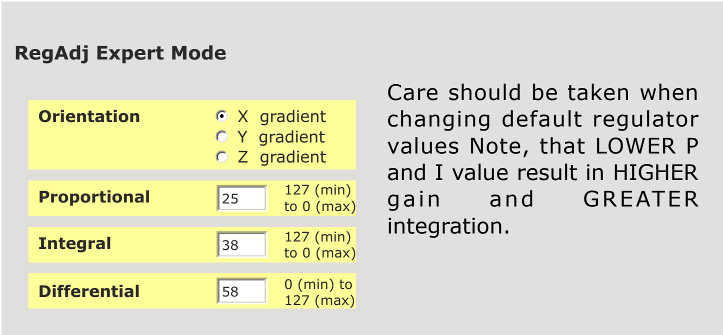


Table Adjustment

The goal of the Table Adjustment is to determine:

- center positioning of the phantom in the magnet iso-center
- sufficient field homogeneity
- distance between light marker and magnet iso-center

The Phantom shim, CTC and ECC procedures require a centered phantom for accurate results. The Table Adjustment determines the phantom position with respect to the center of the gradient coils (iso-center). From this, the distance from the light marker to the magnetic iso-center is determined.

Measurement

The measurement uses a double echo sequence. The first echo is acquired without applying a readout gradient resulting in an FID the length of which is a rough check of the fundamental imaging volume homogeneity.

During the second echo a readout gradient is applied resulting in a signal projection of the phantom. The center of the phantom's signal spectrum is compared to the center of the scan volume frequency window to calculate the phantom position in readout direction. The sequence measures the three axis in this way. Figure 220 shows as example only the X axis.

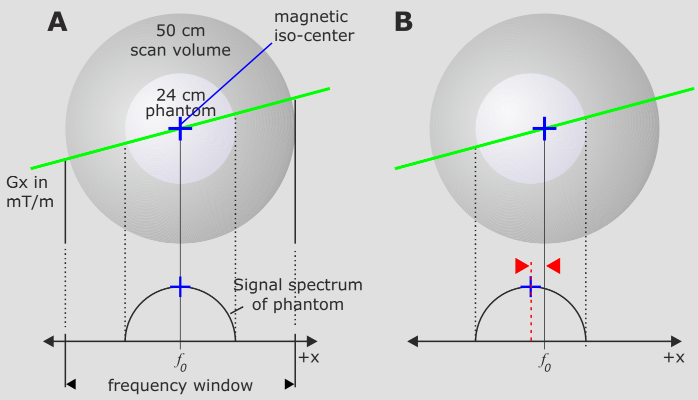
Results

The results of the Z axis measurement is used to determine the table position and will be corrected automatically and stored as the new light marker distance. All three phantom position values are displayed in a table, shown in the table in the graphic. Corrections necessary in the X direction are made by re-positioning the phantom. Corrections in the Y axis may be made by adjusting the table height with the table height-adjust switch SY0 (described in the TSG).

Figure 220 *Table Adjustment Results*

Measurement

Main Menu



With a gradient applied, a linear frequency deviation over distance results providing a Hz/mm relationship.

A If the phantom is centered within the scan volume, the center of its signal spectrum will correlate with the center of the frequency window defined by the applied gradient. The magnetic center of the gradient coil defines the iso-center of the scan volume.

B If the phantom is off-center, its signal spectrum will not be centered to the frequency window. The deviation from center in mm can be derived from the correlation of frequency per mm value known from the gradient amplitude in mT/m.

Result

Phantom Position

	Value	Low Spec	High Spec
X Position	-3	-5	5
Y Position	4	-10	10
Z Position	3	-2	2

Phantom is not centered in z-direction!
Moving patient table by -2 mm.
Correcting patient table distance by 2 mm to 776 mm.

Phantom Shim

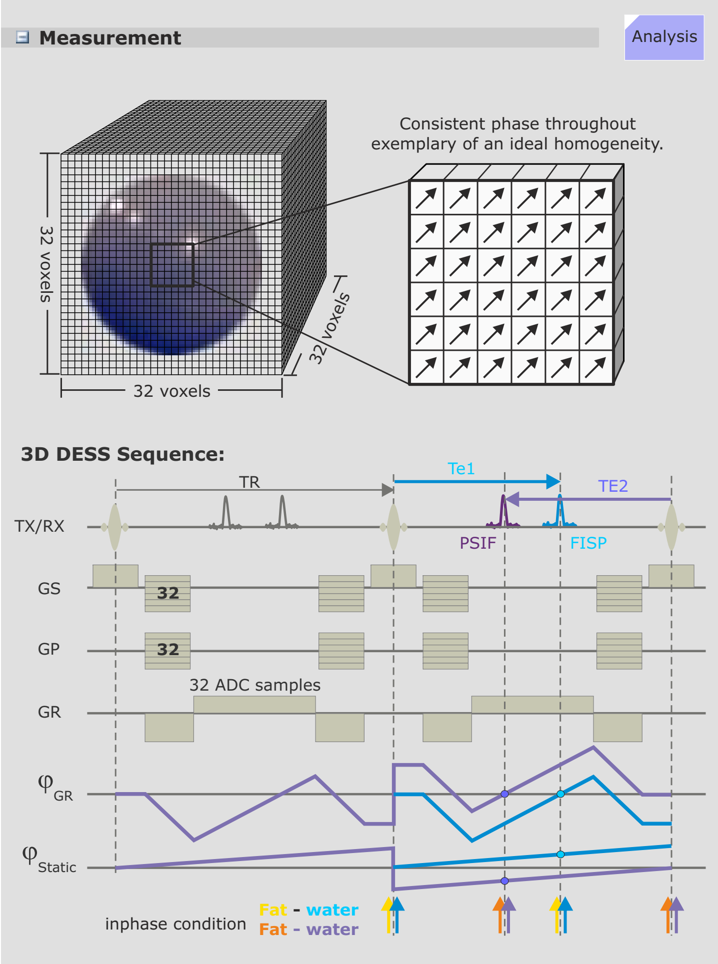
Phantom Shim measures magnet field inhomogeneities and calculates the gradient offset and shim coil currents (option) necessary for optimization. It is performed at this point in the Tune Up set as preparation for the following procedures using the ball phantom for measurement. The correction currents determined here also serve as default values for the pre-sequence adjust shim procedure used for patient imaging.

Background

The phase of an MR signal is directly proportional to the magnetic field. Phantom Shim makes a 3D-measurement, a so-called "Field Map" of the measurement volume using a 32 x 32 x 32 voxel matrix covering a 35 x 35 x 35 cm volume. The resulting voxel volume is about 0.5ml and the voxels are cubes, so the resolution is isotropic. An advantage with this method is in having actual field values for each of the voxels and allows the user to define a specific volume within the measurement volume that is to be optimized. This is called local volume shimming. Also, the evaluation algorithm detects voxels with little or no signal and will not use the data for correction improving the optimization.

To avoid hardware anomalies (e.g., gradient delays or array coil phase errors) it is better to do the measurement with two echo times and examine the phase difference of both measurements. To save time the two echo times can be measured in one sequence using a 3D-DESS-sequence (Double Echo Steady State). The measurement is done twice, for the second measurement all gradients are reversed to eliminate eddy current effects.

Figure 221 *The 3D - Shim Sequence*



Measurement

Shim System Check

First, an operational check of the shim hardware is made. A nominal shim current is applied to each shim channel followed by a shim measurement and the actual field change effect is compared to the expected, predicted field change effects. In this way wrong cabling, wrong polarity, open or short coils can be detected.

Field Map

The sequence is a 3D-DESS sequence, i.e. two echoes, a FISP and a PSIF echo are generated. The echo times - 4.7ms - are so chosen, that fat and water are in phase, hence, the sequence is prepared for patient use as well.

As seen in Figure 221 the Phase_{GR} line represents the phase rotation due to the readout gradient and the Phase_{static} is the phase rotation due to the static field inhomogeneities which is the factor we are looking to determine.

Chemical shift (Fat - Water) = 3.35ppm. We operate with 1.5T:

$$3.35 \cdot 63.6\ \text{MHz}/10^6 = 213\ \text{Hz}$$

$$1/213\ \text{Hz} = 4.7\ \text{ms}$$

Evaluation

For 1.5T systems the echo time difference of FISP and PSIF signals is 9.4ms. This has the shortcoming, that the **true absolute** off resonance-frequencies cannot be analyzed: Due to the Nyquist-theorem the highest frequency which can be analyzed correctly is

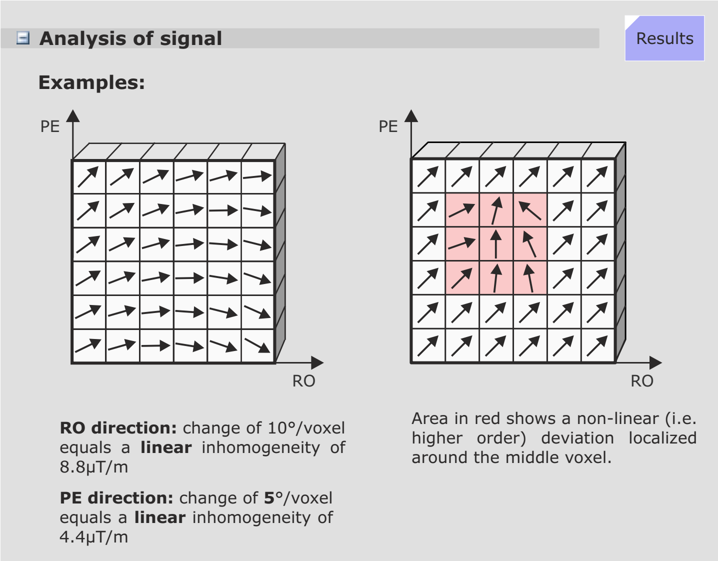
$$1/9.4\text{ms} = \pm\ 53\text{Hz}$$

However, for the check and optimization of B_0 it is sufficient to compare the **field differences** between neighboring voxels. The field difference is obtained by comparison of the phases of the magnetization vectors. With an echo time difference of 9.4ms a shift of 10 degrees from voxel to voxel in one direction results in a linear homogeneity of about 9μT/m in that direction.

The complete data set is evaluated by a differential shim equation. The equation minimizes the difference between:

- the field generated by the three gradient coils and the 5 shim coils
- the measured magnetic field inhomogeneities.

Figure 222 *Phase Rotation Evaluation*



Numerically, the problem is a least square fit leading to a system of many linear equations with 8 unknowns: the 3 gradient offset currents and the 5 shim currents. In short: the comparison of the B_0-fields in two voxels - performed by analyzing the phases - results in one equation. For all voxels 98304 calculations are required. However, a threshold is set for the signal to noise: voxels with no or little signal-noise ratio will be rejected, so the number of equations is typically reduced to about 20000.

Results

The first table displays the measured field terms for each of the 8 terms that can be corrected. The 3 first order field terms and the 5 second order field terms that can be optimized are:

Spherical Harmonic	Field	Correction Device
First Order Terms		
A(1,0)	Gz	Z gradient coil
A(1,1)	Gx	X gradient coil
B(1,1)	Gy	Y gradient coil
Second Order Terms		
A(2,0)	$z^2 - (x^2+y^2)/2$	Shim Coil
A(2,1)	xz	Shim Coil
B(2,1)	yz	Shim Coil
A(2,2)	$(x^2-y^2)/2$	Shim Coil
B(2,2)	xy	Shim Coil

The tables in the graphic below give the correction currents for the gradient and shim coils. The gradient offset current are expressed in mT/m and the shim coil currents in mA.

Expert Mode

No extra functionality is provided by the Expert Mode for either Tune-Up or QA

Figure 223 *Phantom Shim Results*

Results

Main Menu

Field Terms

	Value	Low Spec	High Spec	Unit
Bpp	2.02			ppm
Brms	0.23			ppm
A10	0.67	-0.70	0.70	ppm
A11	0.89	-0.70	0.70	ppm
B11	0.06	-0.70	0.70	ppm
A20	-0.05	-0.70	0.70	ppm
A21	0.04	-0.70	0.70	ppm
B21	0.03	-0.70	0.70	ppm
A22	-0.00	-0.70	0.70	ppm
B22	-0.01	-0.70	0.70	ppm

TU Gradient Offsets Table

	Old		New		Change	
	Value	Unit	Value	Unit	Value	Unit
Gx	0.0011	mT/m	-0.0035	mT/m	-0.0045	mT/m
Gy	-0.0041	mT/m	-0.0044	mT/m	-0.0003	mT/m
Gz	0.0030	mT/m	-0.0011	mT/m	-0.0041	mT/m

QA Shim Currents Table

	Old		New		Change	
	Value	Unit	Value	Unit	Value	Unit
A20	-10	mA	-2	mA	8	mA
A21	43	mA	29	mA	-14	mA
B21	-29	mA	-140	mA	-11	mA
A22	-455	mA	-454	mA	1	mA
B22	-13	mA	-9	mA	4	mA

Cross Term Compensation (CTC)

An applied gradient field in any axis produces not only eddy currents along that axis, but also small amounts of eddy currents are coupled over the conductive magnet components onto the other two axis', the so-called cross terms. The CTC (cross term compensation) procedure measures the eddy currents created by the cross terms. Compensation is made by pre-distortion of the gradient waveform. Cross term amplitudes can be up to 0.2% of the main applied gradient amplitude. Unlike the main eddy currents which are complicated and need to be modeled with 5 time constants, the Cross Term current decay exponentially in time in general with only one time constant.

Measurement

The procedure measures the decay of the eddy currents caused by the cross terms. Amplitudes and time constants of the eddy current contributions are then calculated. The compensation is straightforward: gradient fields of equal and opposite amplitude and time constants to the measured cross terms are applied perpendicular to the main applied gradient field. The result is a much cleaner main gradient with very small residual cross terms improving the final image quality.

Result

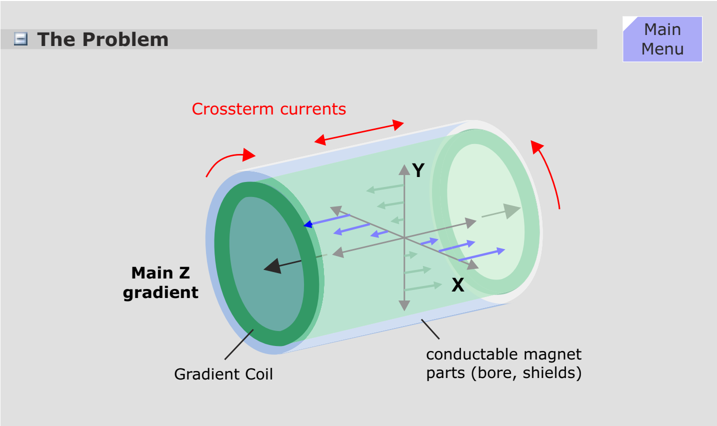
The amplitude and time constants of the compensations are displayed graphically and in tabular form. Only the Z axis is shown.

Expert Mode

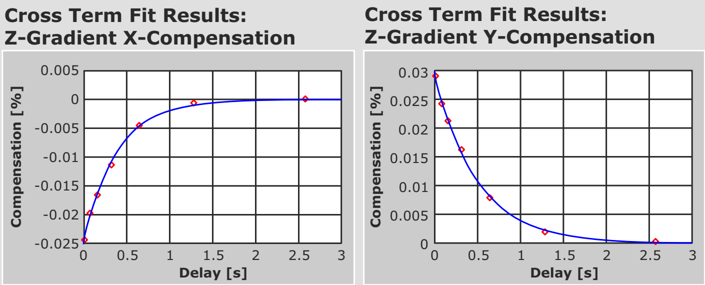
The CTC can be made individually for each axis.

Orientation	○ X gradient ○ Y gradient ○ Z gradient

Figure 224 *Cross Term Currents*



Results



Cross Term Fit Results for Z-Gradient

	Amplitude		Time Constant	
	Value	Unit	Value	Unit
X Compensation	-0.0246	%	0.388	s
Y Compensation	0.0293	%	0.505	s

Eddy Current Compensation (ECC)

The dynamic gradient fields produce currents (called eddy currents) in all the surrounding conductive structures, mainly the Body Coil, magnet bore and the cryo-shields. The eddy currents produce in turn magnetic fields which oppose and distort the applied gradient fields. Eddy currents in the warm components (Body Coil and Magnet bore) have relatively short decay times, whereby eddy currents developed in the cold cryo-shields can have relatively long time constants.

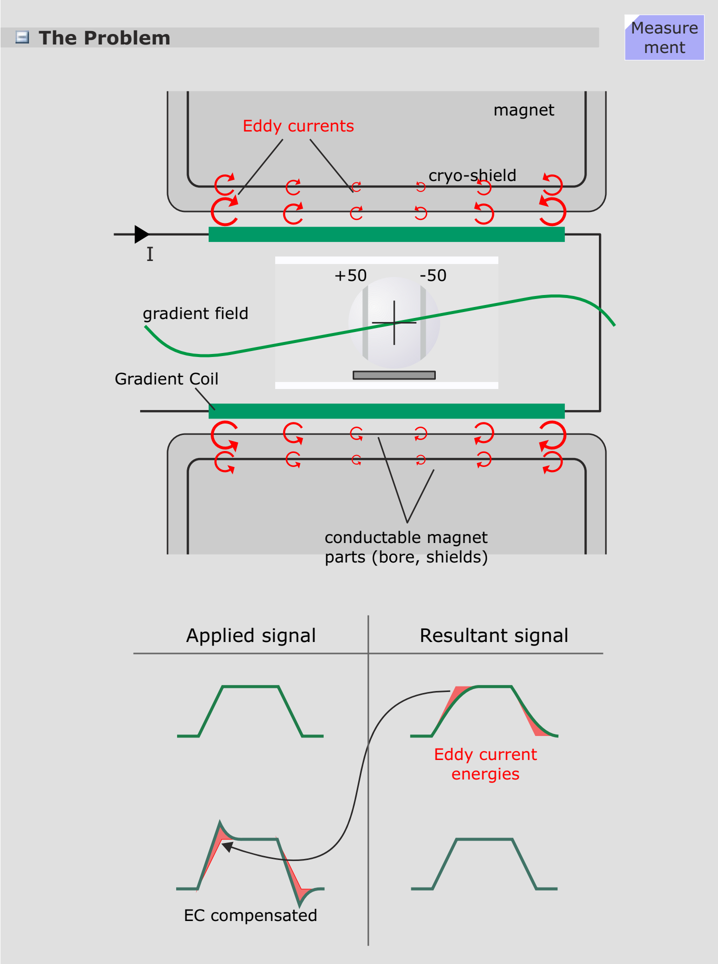
The eddy currents have to be accurately quantified and characterized by their time constants and amplitudes to achieve a good compensation. The compensation is made by adding the reciprocal of the measured eddy currents to the gradient pulse thus neutralizing their effects. For accurate compensation 5 time constants are used.

Spatial Dependency of Eddy Currents

Experience has shown, that for smaller slice shifts it is sufficient to express the eddy fields into a 0^{th} and a 1^{st} order term.

Term	Description
0th	This term arises from an ***asymmetry*** of the gradient coil with respect to the magnet bore and cryo shields. This term is space independent and present in the complete imaging volume and adds to the nominal B_o-Field. The amplitude (x) is given in the unit µTm/mT. The time constant of the most significant 0th term component is about 500ms, although there are shorter time constant components as well.
1st	This is the most important term as it has the same symmetry as the gradient field itself. The amplitude is given in % of the applied gradient pulse.
2nd or above	There are also high ordered eddy currents present, they are usually small and negligible as long as the slice shifts and off center zooms are not too large. No compensation for the high order eddy currents can be made.

Figure 225 *Eddy Current Problem*



Measurement

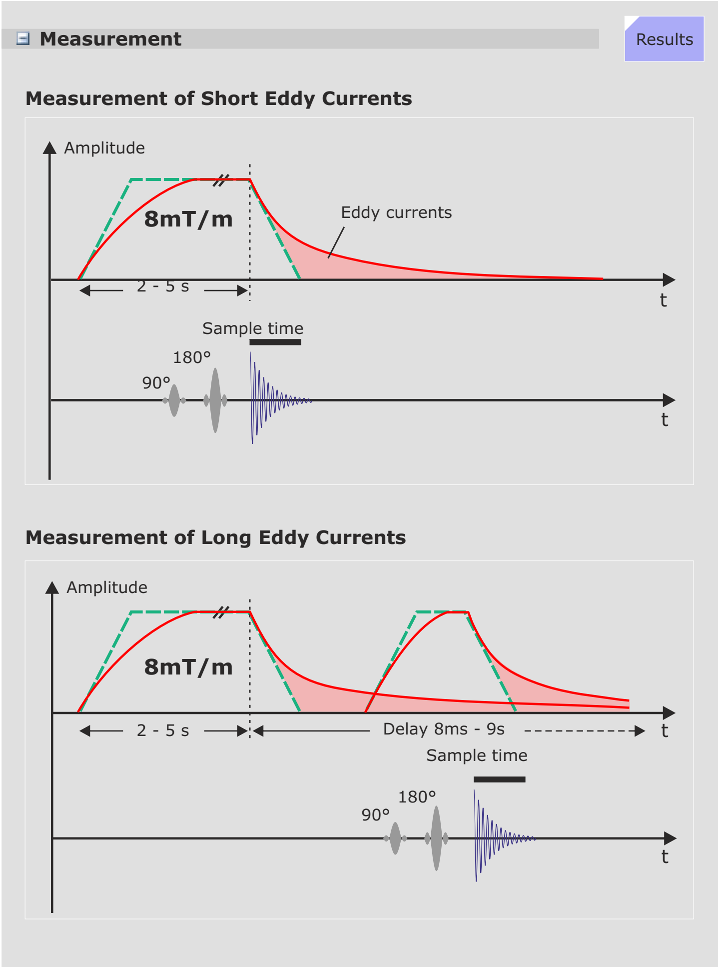
First, the phantom center position is checked. The same preparation measurement is used as for Phantom shim, however, the small spherical phantom is used. If the phantom is not correctly positioned the measurement stops with an error.

The sequence for the measurements generates 23 spin echoes with delay times between 0.4 ms to 9000 ms of the applied gradient.

The measurement is made at the moderate slice shifts of ±5 cm to prevent contributions from higher order terms.

```
V1: Training Center          File: ecct_prep.dat
--------------------------------------------------
2007-03-08 14:47:24  Sequence: eddyprep
Gradient: Echoes:   12          Points:  256 * 30us
Slice Grad  Shift  Frequ  Ampl1  SN  Points  Pos  Ampl2  SN
            [mm]   [Hz]                      [mm]
-------------------------------------------------------------
  1     X    -50     -0    4114  560   254     2   9062  439
  2     X     50      0    3895  468   254     1   8792  344
  3     Y    -50     -5    3730  537   254    -2   8794  541
  4     Y     50      9    4218  334   254    -1   9622  571
  5     Z    -50     -1    3692  324   254     1   8450  480
  6     Z     50      5    3910  393   254     1   8727  498
-------------------------------------------------------------
Phantom Position: X:-0.8mm Y:-1.2mm Z:-1.2mm
Tolerances:          5.0mm    5.0mm    3.0mm
```

Figure 226 *ECC Measurement*



Evaluation

After a measurement - usually two or three iterations are required before the final optimization - the measured data is displayed in a table found in the log file. The first table (not shown) lists the actual measured data at position +50 mm from the first measurement. The second table lists the measured data for the -50 mm position. The third table, shown at right, gives the combined results of both.

Header

There is some basic information given in the header (top section). For example, the sequence generated 23 spin echoes. The delay times can be seen in the list and are between 0.4 ms to 9000 ms of the applied gradient. The gradient amplitude is 8 mT/m, the spin echoes are generated in 3 mm slices with slice shifts of +50 mm and -50 mm. Hence the gradient amplitude in the slices is:

$\pm 8\ \mathrm{mT/m} \cdot 0.05\mathrm{m} = \pm\ 0.4\ \mathrm{mT}$

corresponding to a frequency of

$\pm 0.4 \cdot 10^{-3} \cdot 42.577 \cdot 10^{6}\ \mathrm{Hz} = \pm 17031\ \mathrm{Hz}$

at the slice position +50 mm or - 50 mm resulting in an overall frequency of 34062 Hz. This frequency will be displayed as **Ref. Frequency**.

Signal Nr. 1 is measured for frequency offset. Signal 2 is measured to correct for the eddy currents generated by the slice-select gradient (measurement of long delays).

The data for a given delay time will be rejected if the amplitude **"Ampl"** is less than a given threshold-value. **"Points"** in the last column means the number of ADC-sampling points for the given signal. The shorter the delay time after the gradient, the shorter must be the total sampling time and hence the number of sampling points.

After the sequence was run for the two slice positions + 50 mm and - 50 mm the data first will be added up and then subtracted in order to separate the 0^{th} order term and 1^{st} order term.

Figure 227 *ECC Measurement Data*

Results

```
V1: Training Center          File: ecct_x1.res
--------------------------------------------------
2006-07-27 14:25:48  Sequence: eddy
Gradient: X  8.0mT/m  400us  Hardware: 1
Echoes:    23          Points: 1024 * 10us
Gradel:     2us        Ref.Freq: 34061.0Hz
Position 1:  50.0mm    Position 2: -50.0mm
```

Nr.	Delay [ms]	Gradient [Hz]	Gradient [%]	B0 [Hz]	B0 [uTm/mT]
(1	0.39	158.6	0.466	-32.7	-0.096)
(2	0.56	118.6	0.348	-33.1	-0.097)
3	0.82	97.1	0.285	-31.0	-0.091
4	1.19	89.0	0.261	-32.1	-0.094
5	1.72	85.6	0.251	-31.8	-0.093
6	2.48	82.3	0.242	-31.8	-0.093
7	3.59	79.5	0.233	-31.4	-0.092
8	5.18	77.3	0.227	-31.3	-0.092
9	8.58	73.2	0.215	-31.0	-0.091
10	12.98	71.5	0.210	-31.0	-0.091
11	18.48	70.0	0.206	-31.0	-0.091
12	27.28	67.7	0.199	-30.9	-0.091
13	38.30	64.0	0.188	-30.4	-0.089
14	54.30	61.3	0.180	-29.8	-0.087
15	77.30	58.0	0.170	-28.6	-0.084
16	111.30	54.9	0.161	-26.8	-0.079
17	159.30	52.3	0.154	-24.1	-0.071
18	230.30	49.4	0.145	-20.4	-0.060
19	331.30	46.8	0.137	-15.6	-0.046
20	477.30	43.1	0.127	-9.9	-0.029
21	688.30	35.7	0.105	-4.3	-0.012
22	993.30	25.0	0.073	0.1	0.000
23	1433.30	14.6	0.043	1.9	0.006
24	2069.30	6.6	0.019	1.7	0.005
25	2988.30	2.3	0.007	0.9	0.002
26	4315.30	0.8	0.002	0.2	0.001
27	6232.30	0.5	0.001	0.1	0.000
28	9002.30	0.4	0.001	0.0	0.000

Results

The program has calculated:

Gradient Compensation (1st order term)

```
=========== Gradient Compensation for X ==========
  Current Param.       Change      Suggested Param.
  Time[s] Amp[%]    Time[s] Amp[%]    Time[s] Amp[%]
--------------------------------------------------
 0.100000    0.00| 4.540142    0.00| 4.640142    0.00
 0.010000    0.00| 0.635672    0.54| 0.645672    0.54
 0.003000    0.00| 0.452966   -0.39| 0.455966   -0.39
 0.001000    0.00| 0.048949    0.08| 0.049949    0.08
 0.000300    0.00| 0.001438    0.08| 0.001738    0.08
--------------------------------------------------
  Overshoot =    0.29 %       Fit Quality = 0.044553
```

In this example the overshoot is 0.29% higher than the normal value without eddy current compensation. For the Fit Quality the RMS-value is given.

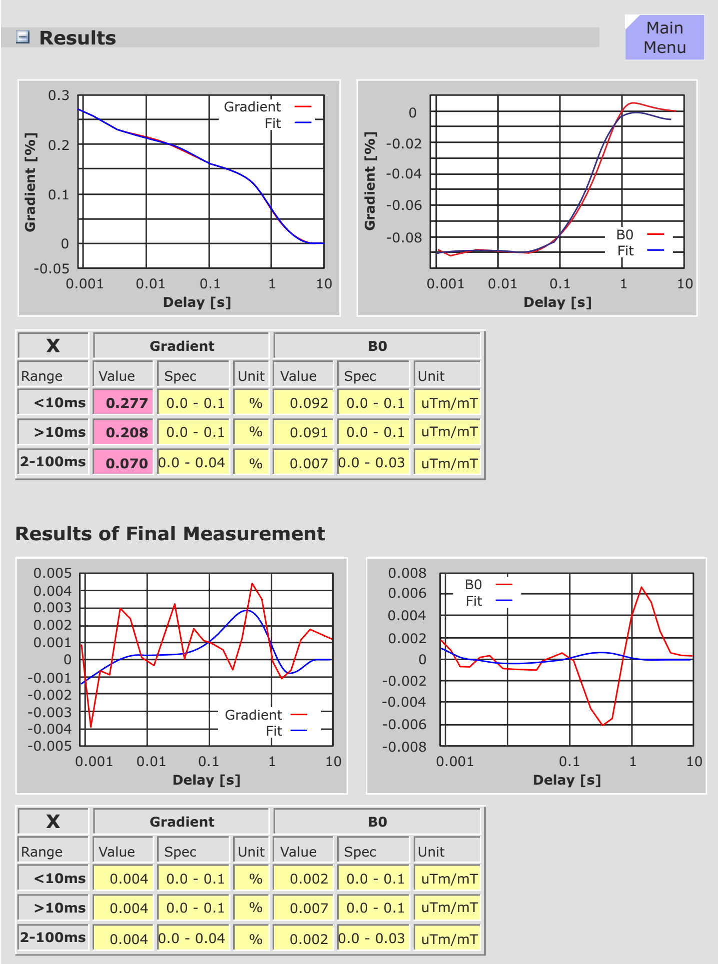
B_0 Compensation (asymmetry)

```
============== B0 Compensation for X =============
  Current Param.       Change      Suggested Param.
  Time[s] Amp[%]    Time[s] Amp[%]    Time[s] Amp[%]
--------------------------------------------------
 0.003000    0.00| 1.996192    0.04| 1.999192    0.04
 0.001000    0.00| 0.699000   -0.13| 0.700000   -0.13
 0.000300    0.00| 0.000505   -0.02| 0.000805   -0.02
--------------------------------------------------
  Overshoot =  -0.10 %       Fit Quality = 0.052512
```

The first plot of the uncompensated eddy fields shows a smooth curve. The next measurement will establish already a large improvement.

The final iteration, usually after 2 or 3 measurements, shows an oscillating pattern indicating the remaining field pertubations are too small to be compensated.

Figure 228 *ECC Results*



Coil Power Losses (CPL)

The purpose of this procedure is to measure the amount of power loss of the Body Coil. This value is used by the RF-Safety Watchdog (RFSWD) monitor to achieve a more accurate SAR measurement.

Measurement

A complete in-line adjustment with a non-volume-selective frequency adjustment is performed, followed by a transmitter adjustment. The voltage from the Adjust/Transmitter result is used to calculate the reference power:

Reference Power from TALES = (Voltage from Adj/Tra)^2 / 50 Ω.

The small spherical phantom is necessary because of the reduced losses in the phantom and the dielectric resonances. A subsequent measurement is made only to verify that the small (17cm diameter) spherical phantom is used and properly centered.

Evaluation

The measured reference power from the TALES is checked. Low Spec = 250 W, High Spec = 630 W. If an oil-filled 170 mm phantom were to be used the low specification might not be reached or if the body loader phantom is in the magnet the high specification might be exceeded. Also, is available, the pick up probe signals will be evaluated, corrected and saved for use in SAR monitoring.

Results

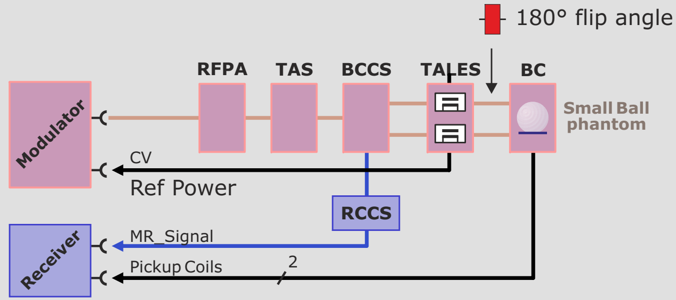
The value for the Coil Power Losses is calculated: CPL = Reference Power from TALES * (1 + σ), where σ is a correction factor taking into account electrical conductivity of the phantom fluid and dielectric resonance effects. The factor σ is greater than 1 so the Coil power loss value is larger than the measured reference power.

Figure 229 *Coil Power Loss Measurement*

Measurement

Main Menu

Adjust Transmitter



Result

Phantom Center

	Value	Low Spec	High Spec	Unit
Phantom Center X	-5.13	-20.00	20.00	mm
Phantom Center Y	3.05	-20.00	20.00	mm

Phantom Diameter

	Value	Low Spec	High Spec	Unit
Phantom Diameter X	169.52	150.00	190.00	mm
Phantom Diameter Y	170.42	150.00	190.00	mm

Ref Power from TALES

Name	Value	Low Spec	High Spec	Unit
Ref Power from TALES	400.11	250.00	630.00	W

Coil Power Losses result 480.13 W saved

Gradient Delay

The gradient amplifiers have a delayed response time (t_{nom} to t_{act}), due mainly to the coil inductance and is slightly different for each of the three gradient axis. The Gradient Delay measurement determines the delay time for each gradient axis. A precise timing of gradient pulses and RF is very important for good image quality.

Measurement

The measurement uses a Spin-Echo-sequence without phase encoding, hence only one line is measured. The gradient to be tested acts as the readout gradient and is switched on once between the 90°- and the 180°-pulse and then again during the readout time of the spin echo.

The first gradient pulse causes a dephase of the magnetization vector in the direction of the gradient axis. The amount of dephase is proportional to the time-amplitude integral of the gradient pulse. Subsequently, a 180° refocusing pulse is applied normally resulting in a spin echo at TE/2 time later. However, due to the dephasing of the vector by the first gradient pulse, the echo will only land in the center of the ADC window (which is also centered exactly around the TE time point) when an equal rephasing gradient has been applied at the proper time so that the rephasing is finished at the center of the ADC cycle.

For a non-corrected gradient delay the two gradient pulses are time-delayed. This does not influence the dephasing effect of the first gradient pulse, however the delayed second gradient pulse causes a rephasing delay and thus a time-delayed echo signal. From the echo signal delay and the gradient amplitude the system can calculate the required correction time.

Difference Deviation Check

Each gradient is measured at three different gradient strengths - 1.5, 4 and 8 mT/m - giving three gradient delays for each gradient. For an ideal gradient system, all delays should be the same.

The **Max. Diff. Deviation** is the maximum difference of the delay times with different gradient strengths, i.e. high gradient pulses may be different from low amplitude pulses. If the tolerance is exceeded, this indicates some kind of nonlinearity in the gradient system.

Results

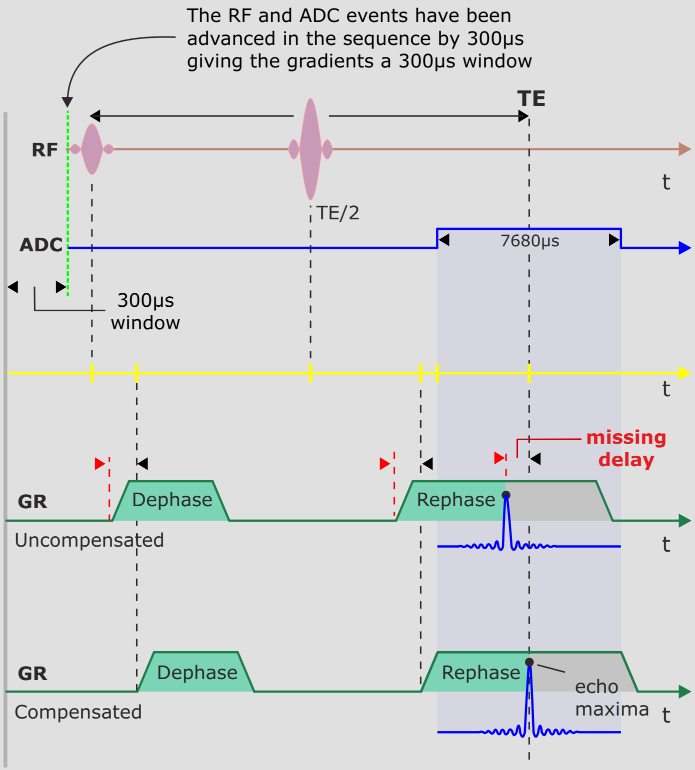
The new delays and maximum deviation values are displayed in two separate tables. If the procedure was successful, the values will be saved.

Expert Mode

No extra functionality is offered in the expert mode.

Figure 230 *Gradient Delay Measurement and Results*

Measurement



Result

Main Menu

New Gradient Delay Values

	Value	Low Spec	High Spec	Unit
X Gradient Delay	13.000	0.000	300.000	µs
Y Gradient Delay	13.000	0.000	300.000	µs
Z Gradient Delay	11.000	0.000	300.000	µs

Max Diff Deviation

	Value	Low Spec	High Spec	Unit
Max diff deviation X	2.000	0.000	5.000	µs
Max diff deviation Y	0.000	0.000	5.000	µs
Max diff deviation Z	1.000	0.000	5.000	µs

New Gradient Delay values saved

Gradient Sensitivity

The purpose of this measurement is to establish the actual LSB weighting (sensitivity) of the gradient amplifier so that accurate gradient field strengths can be calculated assuring accurate FoV (image size).

Nominal Sensitivity

The nominal sensitivity (gradient field / bit) is the nominal gradient strength of the Gradient System (according to option) divided by the digital resolution of the DAC. In the example below, the gradient system has a specified field strength of 40 mT/m and a 20-bit DAC, whereby 1 bit is used for polarity (±10V on the DAC) leaving 19 bits for the dynamic range. This gives a nominal sensitivity of $40mT/m/2^{19}$ = 0.07629 µT/m. The first Gradient Sensitivity measurement will use this value. As can be seen in the first image results, the phantom has the shape of an oval.

Actual Sensitivity

The actual sensitivity, however, will depend on the characteristics of the DAC, the amplifier and the coil. In order to determine the actual gradient sensitivity an **object of known diameter** (the large 24 cm spherical phantom) is measured using a 35cm FoV. and the resultant image evaluated and the actual phantom diameter determined. The actual sensitivity is the old value time the correction factor which is determined by dividing the nominal phantom diameter with the actual measured image diameter.

Table Distance

During this procedure the patient table distance - the distance from the light localizer to the iso-center - is also measured (again, it was first measured some steps ago) and, if necessary, automatically corrected. If a correction is necessary the measurement is repeated.

Measurement

The gradsens sequence is a standard Gradient Echo (FLASH) sequence with a TR = 50 msec, TE = 10 msec. The sequence is run three times, one for each orientation. For the sagittal orientation the usual orientation of the readout and phase encoding gradients are swapped.

Evaluation

The 24cm phantom is measured and checked initially for size and center.

Results

Afterwards the three values for the gradient sensitivity will be stored in the status file.

In addition, the Grad Sens program is used to determine the distance from the light marker to the gradient coil center.

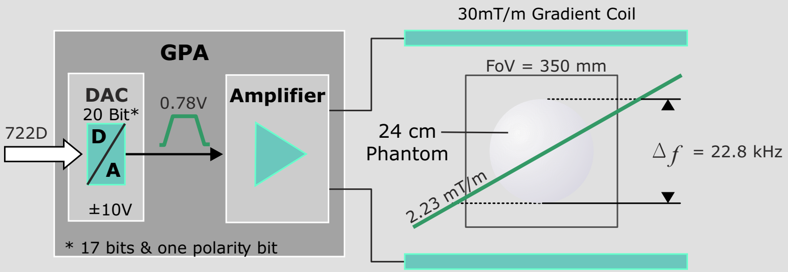
Expert Mode

No extra functionality is offered in the expert mode.

Figure 231 *Gradient Sensitivity Measurement and Results*

Main Menu

Measurement



Sequence

PBW = 130 Hz
MA = 256
FoV = 350 mm

$$GR = \frac{PBW * MA * 1/FoV}{42.577}$$

GR = 2.23 mT/m

Analysis

Default Sensitivity

$$= \frac{40mT/m}{2^{19}}$$

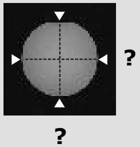
$$= 0.07629\ \mu T/m\ (LSB)$$

Actual Sensitivity

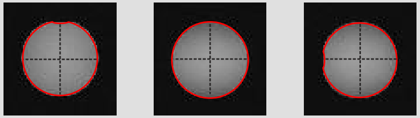
$$\text{New Value} = \text{Old value} \cdot \frac{\Delta f\ \text{Actual}}{\Delta f\ \text{Nominal}}$$

(2.23mT/m * 0.24m) * 42.577MHz/T = Δf *nominal in kHz*

Image



Result



Phantom Position

	PhaseEnc		ReadOut		Average	
	Value	Unit	Value	Unit	Value	Unit
X Position	-0.5	mm	-0.5	mm	-0.5	mm
Y Position	+3.5	mm	+3.6	mm	+3.6	mm
Z Position	+3.3	mm	+3.5	mm	+3.4	mm

Phantom Diameter

	PhaseEnc			ReadOut			Average		
	Value	Spec	Unit	Value	Spec	Unit	Value	Spec	Unit
Diameter X	240.4	238 - 242	mm	239.9	238 - 242	mm	240.1	238 - 242	mm
Diameter Y	240.0	238 - 242	mm	240.3	238 - 242	mm	240.1	238 - 242	mm
Diameter Z	241.3	238 - 242	mm	239.5	238 - 242	mm	240.4	238 - 242	mm

Gradient Sensitivities

	Current		New	
	Value	Unit	Value	Unit
Sensitivity X	0.00007629	mT/m	0.00007957	mT/m
Sensitivity Y	0.00007629	mT/m	0.00007887	mT/m
Sensitivity Z	0.00008583	mT/m	0.00009031	mT/m

Saving new gradient sensitivities to GPA.

Moving patient table by -3 mm.

Correcting patient table distance by 3 mm to 778 mm.

Receive Path Calibration

General

The image quality of an MR system is distinguished by its signal-to-noise ratio and the uniformity of the image brightness which are parameters influenced mainly by the quality of the RF receive coils (coil sensitivity and B1 field homogeneity) and the receive path components (amplifier noise figures, etc.).

This presents a problem. Each receive coil will have a specific signal intensity (= mean value of image brightness) which is determined by the type (LP, CP, volume or surface) and design (size, gain and sensitivity) of the coil. It is necessary, therefore, to normalize the signal intensity of each coil to a value of 2000 for water, which is the basis of MR imaging, so that the image intensity of the final image is the same regardless which coil is used. To do this the coils have been measured here at the factory and assigned a correction factor, called the **RefFFTscale,** which is used by the Imager to normalize the signal intensities of the received signals.

An advantage of the **Tim** technology is the ability to combine coils for extended FoVs as well as the positional flexibility of coils such as the Body Matrix, PA Matrix and Flex coils. To support **Tim**, a receive path consisting of 10 coil plugs having in total 64 receive lines have been provided. Each receive line has its own switched gain amplifier (SGA). Any of the 64 receive line inputs can be routed to any one of up to 32 receive channels consisting in turn of connecting cables of various lengths and receive circuits which includes an ADC. This flexibility of hardware also presents the same problematic of signal intensity deviations mentioned above (refer to Figure 232). Each switched-gain amplifier will have a slightly different gain, and different amplification and phase shift of the signals phase at each gain level. Each transfer cable a slightly different attenuation due to its length. And each ADC will have a different characteristic. Since any coil can be connected to any receiver channel deviations to signal levels will occur causing differences in signal intensities. It is the purpose of the Receive Path Calibration to measure these hardware differences and provide software correction factors that can be applied to the received signals in accordance to the receive channel being used. The corrections are performed by the PCI_RX boards in the Imager.

The procedure is performed in two parts:

- Relative Receive Path -
- Absolute Receive Path

Switch Matrix Input to Output Characteristics

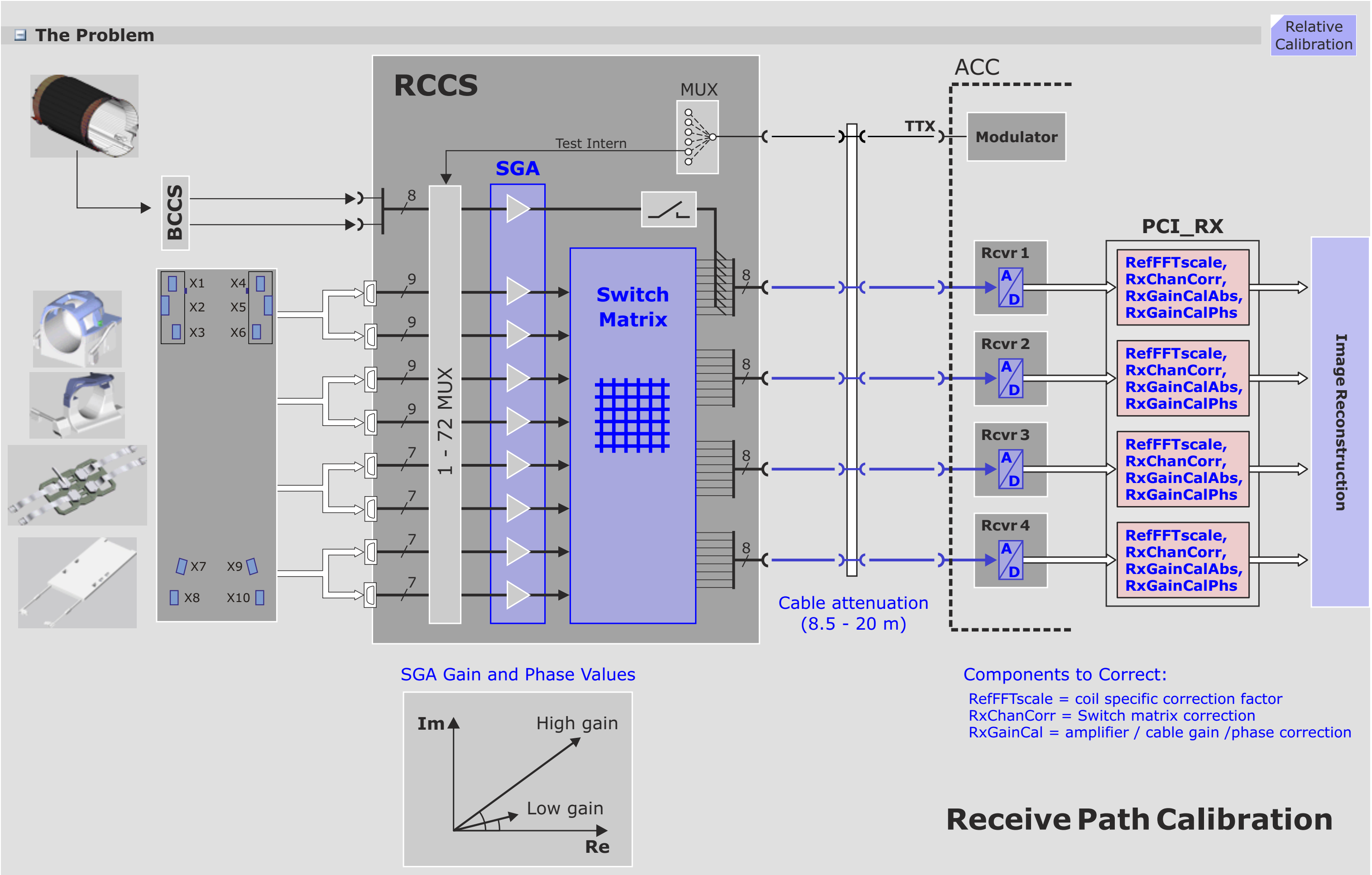
The determination of the correction factor for each input/output selection of the RCCS (ReceiverPathCalibration factor). The factor compensates for the different sensibilities of the individual switch node gains.

RCCS Amplifier Gain and Receive Cable Attenuations

The switched gain amplifiers (SGA) in the RCCS have a high and low gain mode. For 2d sequences they are set to a pre-determined level according to each coil (usually high for most coils) and will not change during the sequence. For 3D sequences, however, large volumes are being excited and the MR signals, especially at the center phase steps, will be large and could overdrive the SGA when kept in the high gain mode. For this reason, the gain will be switched between low and high gain during the sequence. It is therefore necessary that the gain ratios and phase differences of the two amplifier gain modes be determined for accurate post-processing of the raw data. This factor is called **RxGainCalibration** factor and is a complex number determined for each preamplifier by the Receive Path Calibration procedure.

There are 6 different cable sets that can be ordered for the Avanto and Espree systems which have differing lengths and thus different attenuations. These need to be taken into account as well. This also is included in the **RxGainCalibration** factor mentioned above.

Figure 232 *Receive Path Calibration Measurement and Results*



Relative Receive Path Calibration

Measurement

The Relative Receive Path Calibration uses he TTX signal from the Modulator for this measurement. These measurements use the service sequence rx_cal. The return signals are then evaluated by software and the hardware specific factors saved.

In addition to the brightness correction, another factor is calculated for each RCCS input channel: the relation of signals for high and low receiver gain. This factor (Receiver Gain Calibration Factor) is needed for sequences where dynamic gain switching of the RCCS SGAs is used during the measurement. A correction is necessary to avoid image artifacts.

Calibration of RCCS input-matrix

The following steps are performed:

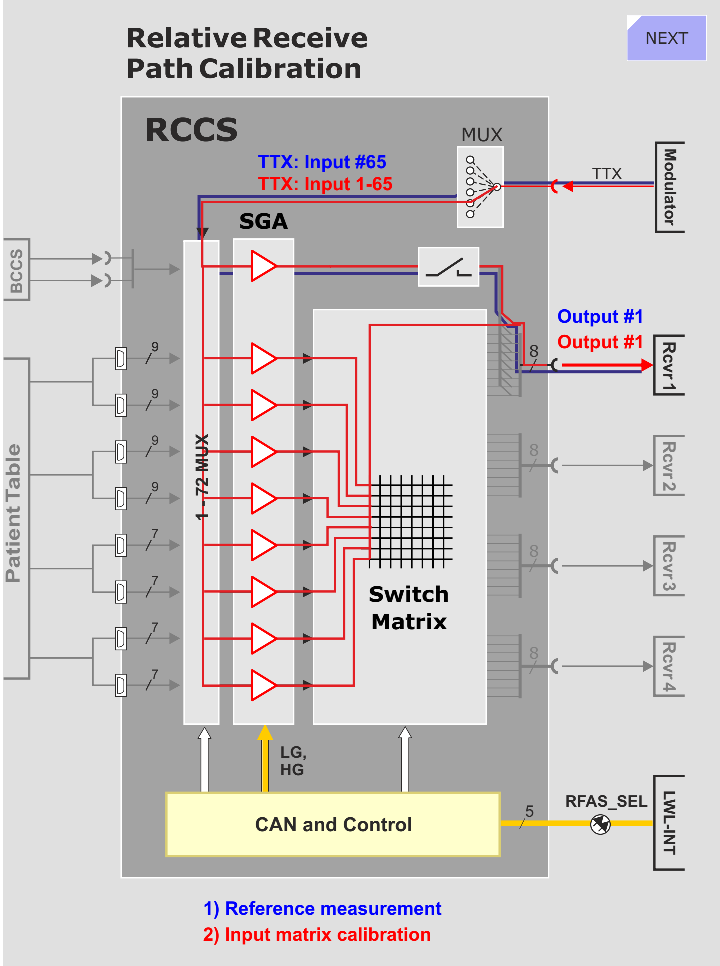
- Raw data evaluation from the reference measurement, low/high gain noise, low/high gain amplitude (graphic representation)
- Raw data evaluation from input channel #1, low/high gain noise, low/high gain amplitude (graphic representation)
- Measurement data from RCCS input channels 1 - 65

Calibration of RCCS output-matrix

The following steps are performed:

- Raw data evaluation from the reference measurement, low/high gain noise, low/high gain amplitude (graphic representation)
- Raw data evaluation from output channel #1, low/high gain noise, low/high gain amplitude (graphic representation)
- Measurement data from all available output channels (1 - 32 max.)

Figure 233 *Receive Path Calibration: Steps 1 and 2*



2. Calibration of RCCS Input Matrix

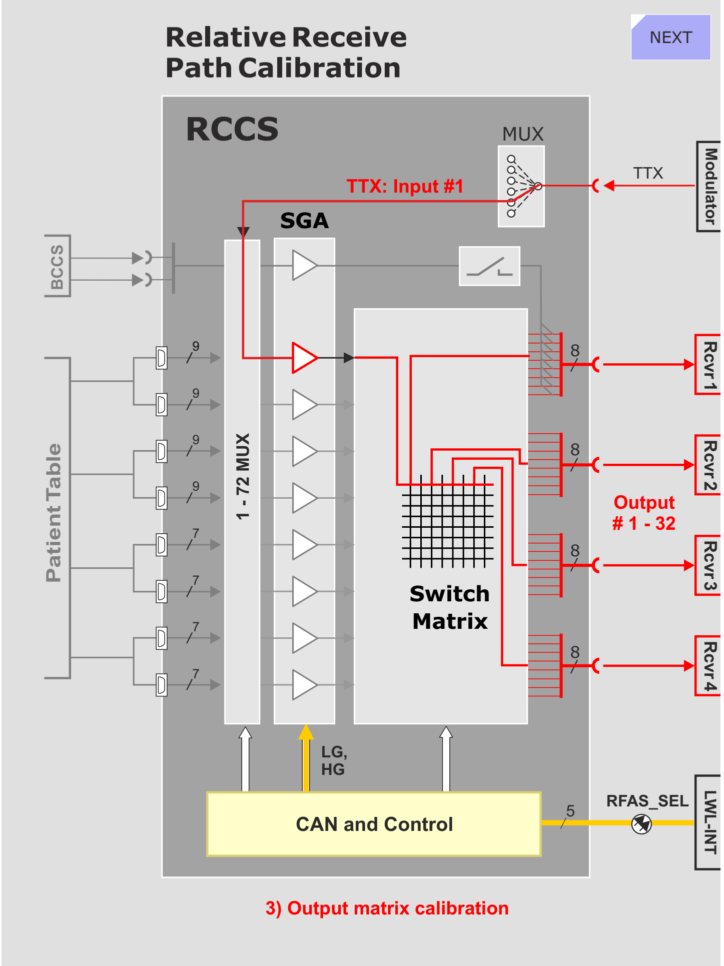
- **Reference Measurement** (Input channel #65, Output channel #1)
  From now on the TTX signal is used for calibration. For the reference measurement signal TTX is fed into Input Channel #65 and uses Output Channel #1. This measurement is done twice: the SGA is switched to low gain and to high gain. The Software evaluates the receiver Gain Factor (difference between low gain and high gain) and the High - Low gain phase difference.
- **Measurements of Input channels 1- 65** (Input channel #x, Output channel #1)
  For the other input channels the TTX signal is fed into input channel 1to 64 (2 measurements with low gain and high gain) and uses always output channel 1. These signals are compared with the result from the reference measurement. Finally, input channel 65 - output channel #1 is measured once more. The result is compared to **2.a**.

3. Calibration of RCCS Output Matrix

- **Reference Measurement** (Input channel #1, Output channel #1)
  TTX signal is fed into input channel 1 and routed to output channel 1, the SGA is switched to low gain and high gain, respectively.
- **Measurements of Output channels 1 - 32** (Input channel #1, Output channel #x)

  TTx signal is fed into input channel 1 and routed to output channel 1, 2,...32. In this way the characteristics of all 32 channels in the 4 Receivers are measured.

Figure 234 *Receive Path Calibration: Step 3*



Results

1. RxChannel Correction

These correction factors run from 1 to 32. The gain of the 32 output channels in the 4 Receivers are described.

2. Mux Channel Correction

Runs from 1 to 65. These correction factors describe the influence of the different input channels.

3. Receiver gain Calibration factor

Runs from 1 to 65. These factors characterize the preamplifiers. The preamplifier can be switched to high and low gain. The absolute value of the ReceiverGainCalibration factor describes the ratio of the magnitudes of the high and the low gain signal. The **phase factor** describes the phase difference of the high and low gain signal.

Figure 235 *Receive Path Calibration Results*

Main Menu

RX Channel Correction

	Old			**New**		
	Value	Low Spec	High Spec	Value	Low Spec	High Spec
#1	0.87			0.88	0.50	1.50
#2	0.87			0.87	0.50	1.50
...						
#17	0.86			0.87	0.50	1.50
#18	0.89			0.90	0.50	1.50

MUX Channel Correction

	Old			**New**		
	Value	Low Spec	High Spec	Value	Low Spec	High Spec
#1	0.96			0.96	0.50	1.50
#2	0.97			0.97	0.50	1.50
...						
#64	0.90			0.89	0.50	1.50
#65	1.01			1.00	0.50	1.50

Receiver Gain Calibration factor

	Abs Old	**Phase Old**		**Abs New**				**Phase New**			
	Value	Value	Unit	Value	Low Spec	High Spec	Unit	Value	Low Spec	High Spec	Unit
#1	5.99	167.80	deg	5.99	4.50	6.50		167.81	-180.00	180.00	deg
#2	5.94	168.00	deg	5.94	4.50	6.50		168.01	-180.00	180.00	deg
...											
#64	5.90	168.08	deg	5.90	4.50	6.50		168.08	-180.00	180.00	deg
#65	5.91	168.09	deg	5.91	4.50	6.50		168.10	-180.00	180.00	deg

Absolute Receive Path Calibration

The Absolute Receive Path Calibration is performed with the **Body Coil**, using the large spherical phantom with loader. The results from this adjustment are used to get correct brightness for images obtained by all coils including local Tx/Rx - coils and receive-only local coils.

1. Image with Body Coil

First an image with a standard sequence is measured with the Body Coil **(Input Channel #65)** and receiver channel 1 **(Output Channel #1)** using a scale factor (RxChannelCorrection Factor) that is preset or using the scale factor from the last receive path calibration measurement. The image brightness and the signal to noise ratio (S/N) is determined from the image. The **RxChannelCorrection** factor of the first receiver channel is determined by correcting the preset scale factor (RxChannelCorrection Factor Old) so that the image brightness becomes 2000.

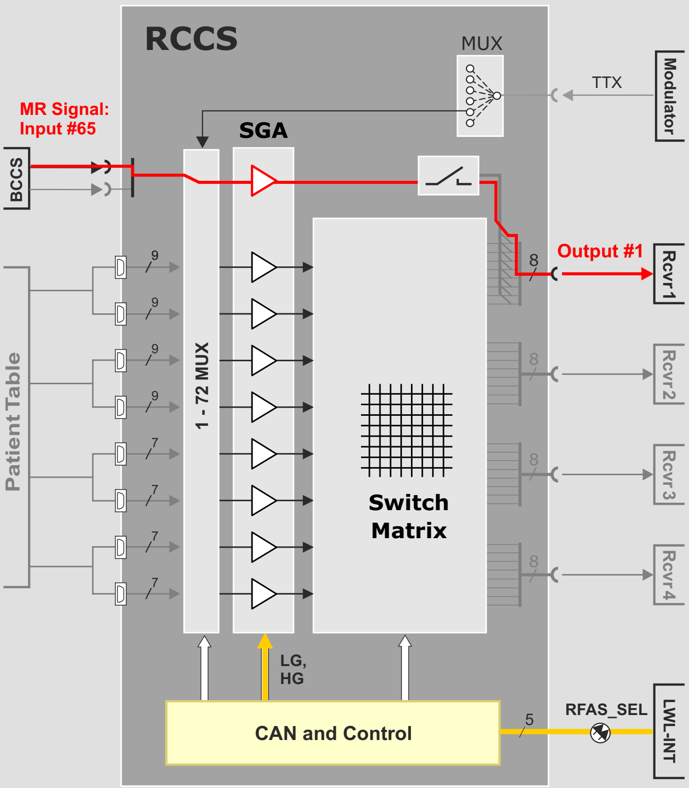
Results

The following steps are performed:

- Acquisition of an MR-Image with protocol Body_Tra_sn
- Image brightness check against specifications
- Combined RX Channel Correction - fine adjustment of the previously measured (Relative Receive Path Calibration) output channel correction factors (1 - 32max.).

__Figure 236__ Absolute Receive Path Calibration Results

Absolute Receive Path Calibration



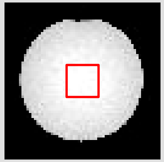


Image Brightness Results

	Value	Low Spec	High Spec
Protocol	Body_Tra		
Brightness (ref.:2000)	1935.80		
S/N	31.79	26.00	
RXChannelCorr Factor Old	1.02	0.50	1.50
Brightness Correction Factor	1.03	0.50	1.50

Combined RX-Channel Correction

	Old			New		
	Value	Low Spec	High Spec	Value	Low Spec	High Spec
#1	0.87			0.88	0.50	1.50
#2	0.87			0.87	0.50	1.50
...						
#31	0.86			0.87	0.50	1.50
#32	0.89			0.90	0.50	1.50

Quality Assurance

The QA procedures are a set of procedures which are used to verify system performance and include all the procedures found in the Tune-Up as well as additional procedures for testing overall system performance. Only these will be described since those procedures found in Tune-Up are identical, with the exception that no values are saved:

- If you are out of specification after a Quality Assurance step, you must perform the corresponding Tune-Up step.
- Every Tune-Up and Quality Assurance procedure can be run in either Normal or Expert mode with one exception: the "field stability" procedure under Quality Assurance (very useful during shim procedure or trouble shooting stability problems) can only be run under Expert mode.

Go back to MAIN MENU

Coil Check

For the LC coils this procedure determines:

- Signal to noise ratio S/N
- Image brightness
- Image uniformity (inhomogeneity)

One or more protocols have been defined for each coil. After each protocol is measured, the routine will analyze the resulting image or images for S/N and in some cases the image intensity profile and image size. For transmit-capable coils the specific absorption ratio (SAR) is checked as well.

In standard mode and for coils where only one phantom position is necessary, the procedure performs all required measurements without user intervention. If more than one protocol is required, the procedure measures and evaluates each image from the protocol before continuing with the next protocol. For coils that require more than one phantom position to perform all the required SN_DIP protocols, the user will be guided on screen through the various phantom positions.

Expert Mode

Expert Mode lets the user select the protocols to be performed. A list of available protocols is displayed. Any combination of protocols can be selected. When selecting Start from the QA platform, the selected protocols will be performed.

Go back to MAIN MENU

Image Orientation

The 6 electrical connections of the Gradient Coil are checked here. If any of the amplifier or coil connections are swapped between two (or more) axis or any of the polarities of any axis is swapped, the orientation of the image will not be correct. This procedure will determine if the connections are correct and if not, which ones are or could be wrong.

The check for correct gradient coil connections is performed in two steps:

- First, for swaps between the three axis (x to y, y to z, etc.).
- Second, for correct polarity of each axis.

The Image Orientation procedure measures the position of the loaded phantom and the spherical phantom in order to determine the correct gradient orientation and polarity.

Measurement

Two images are generated, the first being an axial image in the transversal orientation and the second being an axial image tilted from the transversal orientation -45° to the sagittal direction (see diagram below).

With the first image the correct connection of the gradient cables (x/y/z axis swap) are tested. With the second image the correct polarity of the gradient cables are checked.

In case of incorrect gradient axis orientation, polarity or positioning of the phantom, the procedure will finish with an "error".

Evaluation

The two measured images are automatically evaluated following the measurement. If the phantom is not in the expected position the program evaluates the image and eventually makes further measurements to identify the cause.

Axis Swap

Because the image of the loader is not symmetrical with respect to interchanging of gradient axes, an exchange of gradient axes (i.e. wrong cable connections) can be detected.

The program searches for the outer edges of the loader phantom from all sides and compares it to the expected geometry. If correct, it will continue on to the polarity swap measurement.

If, however, a swapped axis is identified, the program terminates with the report of the axis which are swapped. A reversed polarity check will not be made since this would only make sense when no axis-swap is present. after fixing the swapped axis problem, the program must be made again.

Polarity Swap

Incorrect gradient polarity can be detected by identifying the position of the unsymmetrical fill-cap of the spherical phantom. If the fill-cap is not in the expected position the program will make further measurements and reversing the gradient polarities until the fill-cap is found. When the fill-cap has been found the program terminates and reports which gradient axis or axis have been swapped.

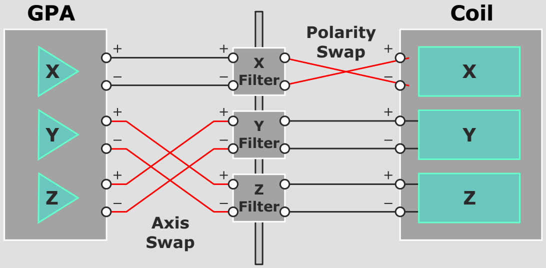
Expert Mode

The only difference in Expert Mode is that no data are written into the database.

Figure 237 *Image Orientation*

Main Menu

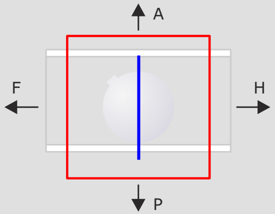
The Problem



Measurement

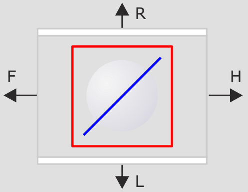
Axis Swap

Orientation: **Transversal**
FoV: **500**

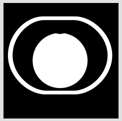


Polarity Swap

Ori: Oblique Tra > Sag -45°
FoV: 300



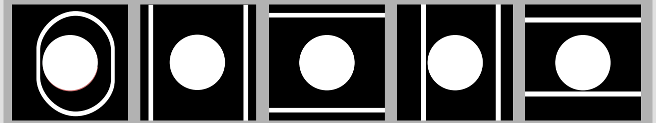
Correct image results:



Loader phantom and large ball phantom are used.

Result

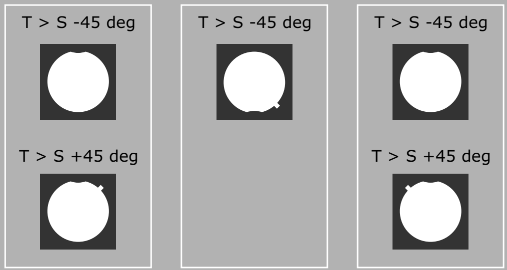
Axis Swap Examples:



x > y	x > x	**x > z**	**x > y**	**x > z**
y > x	**y > z**	**y > x**	**y > z**	y > y
z > z	**z > y**	**z > y**	**z > x**	**z > x**

[GPA > coil]

Polarity Swap Examples:



x swap **y swap** **z swap**

Image Orientation check failed!

The location of the phantom filling opening was identified in the wrong direction.

The _ and _ axis might be ok.

The _ axis may have wrong polarity.

Calculation Artefacts

The Calculation Artefacts (CalcAr) QA procedure is used to quantify the artefact magnitudes (i.e. signal intensities found *outside* the image). Artifacts in MR images can be produced by a variety of mechanisms. For example, gradient deficiencies (instability, non-linearity, 50/60Hz ripple) or RF instabilities will produce periodic blurring or ghosting in the direction of the phase encoding.

Sequence

Calcar is a double-echo Spin Echo sequence run in all three slice orientations at the iso-center (slice shift = 0). The transverse orientation is performed first, followed by the sagittal measurement and the coronal measurement. (Note: for the SAG slice orientation, the Z-gradient is used as phase encoding gradient.)

Evaluation

For a good description on the use and interpretation of the CalcAr results refer to the Tune-Up section of the TSG under QA Troubleshooting Tables.

Expert Mode

Expert Mode lets the user select the slice shift 0, 50 mm, and the three slice orientations separately.

The Evaluate option allows to evaluate any image in the actual segment for artifacts.

Figure 238 *Calculate Artefacts*

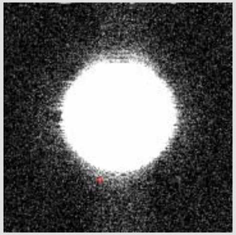
Measurement

Main Menu

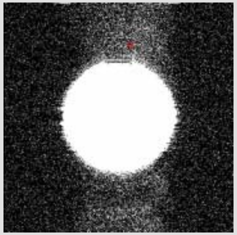
sequence calcar
Transversal
FoV 500.0*500.0 (width*heigth)
256*256 (Lines*Columns)
TR 600.00
TE 35.00, 105.00

Results

Transversal 1. Echo



Transversal 2. Echo



Artifacts for Transversal

	Value	Low Spec	High Spec	Unit
slice shift 1	0.000			mm
Transversal_Artifact_Echo1	0.780	0.000	2.000	%
slice shift 2	0.000			mm
Transversal_Artifact_Echo2	1.034	0.000	3.000	%

Spike Check

The Spike Check looks for occurrences of "spikes" or RF interference. Moving components (usually caused by the pulsed gradients) in the RF room can cause electrostatic buildup and discharges which, if picked up by the RF coils during the measurement, create "spikes" within the raw data. Spikes are very short in time and fill only one or a couple points in the raw data set and will have amplitudes above the typical noise level. How the spikes affect the image depend on where the spikes are in the raw data set and how big their amplitudes are. Typical patterns in the image caused by spikes can be seen as a periodic intensity modulation or structure and can occur diagonally or even straight and in any direction.

Testing Method

The spike sequence starts with an initial series of strong gradient pulses of both positive and negative polarities on all three gradients intended to cause a buildup of static electrical energy caused by any moving components (cables, covers, etc.). The ADC is then enabled and again a pattern of gradient pulses with amplitudes ranging from max positive to max negative are applied. Any static electrical discharges caused by moving or loose parts will picked up by the receiving coil (usually the body coil) and ADC and stored in the raw data. The evaluation looks for intensities in the raw data set exceeding a threshold (usually noise) and counts both the number and intensities of the spikes and displays them numerically and graphically. The electrical discharges will be seen as "spikes" in the raw data. The position of the spikes in the raw data set relates to the gradient that was on when the spike occurred which may give an indication of the direction in which the cause of the spike may be found.

Advanced Spike Check

TRUFI and HASTE sequences and sequences used for EPI or BOLD-Imaging may generate spikes which cannot be verified by the normal "Spike Check". In these cases the "Advanced Spike" can be used for spike trouble shooting. The "Advanced Spike" should be repeated at least three times to be assured the system is free of spikes. But be aware, if there weren’t any spike-causing problems present before using this measurement, there may be afterwards!

Results

The measured raw data and RF-interference images will be loaded and displayed. Image windowing is done by clicking and dragging the mouse or by direct input of image window and center values.

The same algorithm for spike searching is applied to both image data and raw data. In case of image data (RF-interference in the image), the spikes are RF-interference patterns that have been picked up during the noise measurement and then fourier transformed resulting in a spike in the image data, i.e. the RF-interferences will result in pixels of increased intensity in the image data.

Clicking Log-File in the HTML output page lets you open additional windows displaying the Spike Check results:

- Total number of spike positions
- Number of spikes found in real and imaginary part
- Number of spikes correlated in real and imaginary part
- Position (column, row) of spikes
- Amplitudes of spikes in real and imaginary part
- Magnitude of the highest spike
- Threshold for spike discrimination

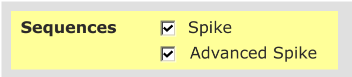
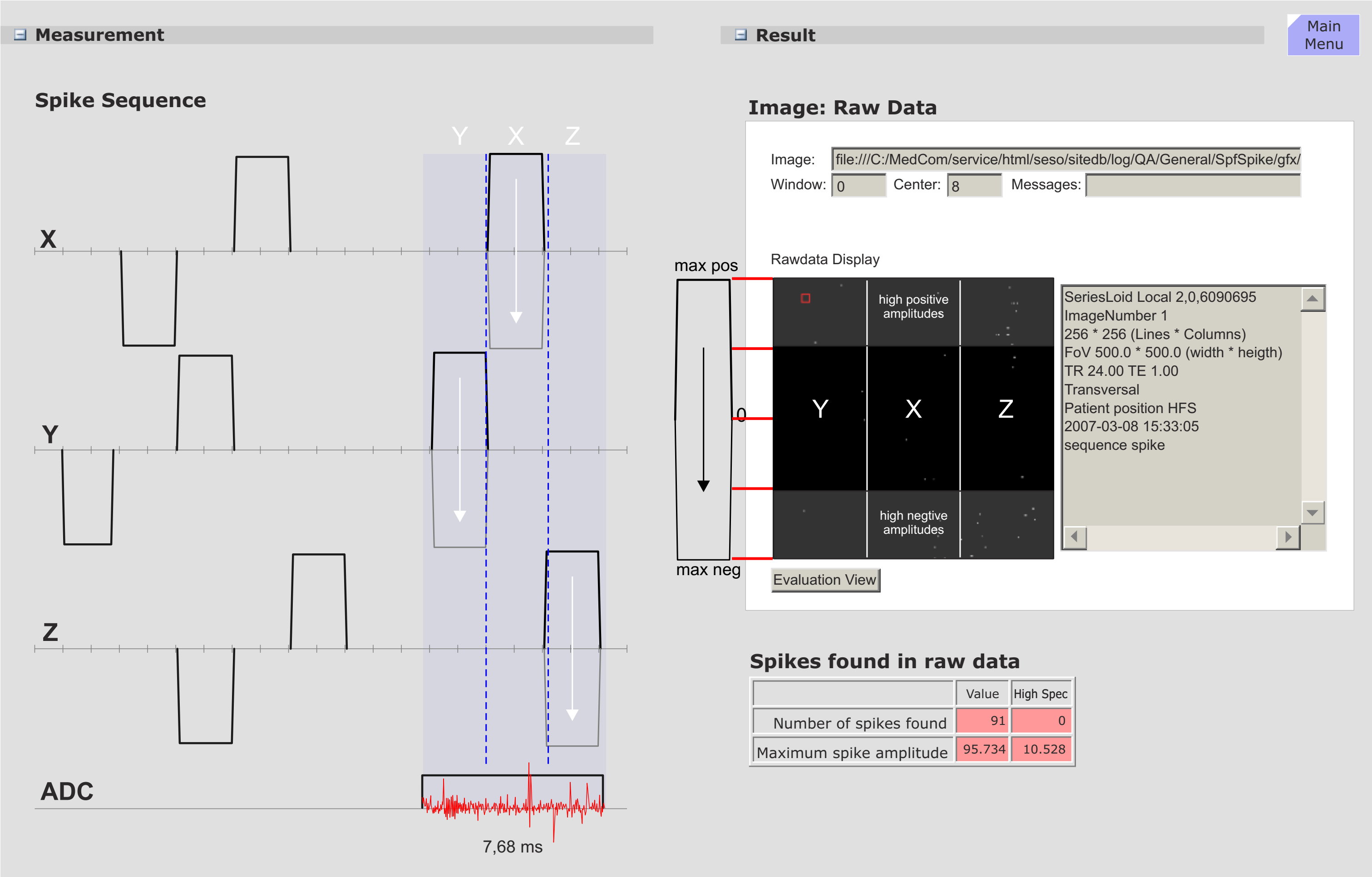


Figure 239 *Spike Check*



Stability Check

A large number of MR signals are required for an MR image and the time necessary to acquire them relatively long, usually in the order of minutes, requiring a high degree of **stability** and **reproducibility** from the field generating units: RF, gradients, magnet, shim. Instabilities caused by ***any*** of these units results in smearing (ghosting) artefacts making a determination of the responsible unit nearly impossible. The Stability Check is a very useful tool to help determine which of the field generating units may be responsible for instability artefacts.

Measurement

The stability test consists of a series of measurements using both spin echo and gradient echo sequences. These sequences are **without phase encoding** so all echoes should be identical. All three orientations are measured so that each gradient is performed as a read-out gradient. In addition, measurements are made at center and off-center (+50 mm) positions.

Spin Echo

The spin echo sequence is in general more sensitive to RF instabilities because the echoes are produced by the 180° RF refocusing pulse. The default TR and TE times of 301ms and 20ms make this sequence also sensitive to 50/60 Hz and is useful to determine influences from the lines power.

Gradient Echo

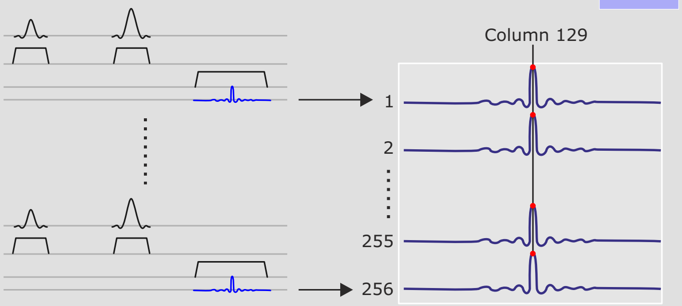
Gradient echo sequences are more sensitive to gradient instabilities since the echoes are a generated by the de- and rephasing of the readout gradient.

This sequence is also sensitive to external field influences up to a few Hz which may be caused by mechanical vibrations (e.g, cold head).

Figure 240 *Stability Check Measurement*

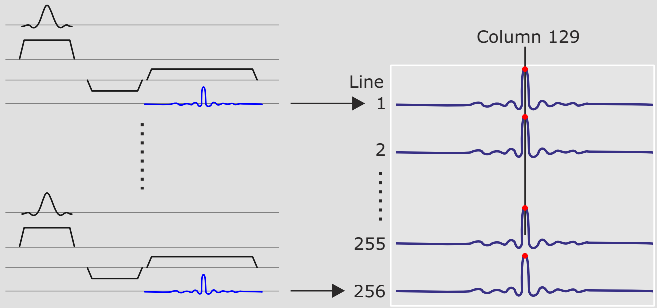
Protocol SE

NEXT



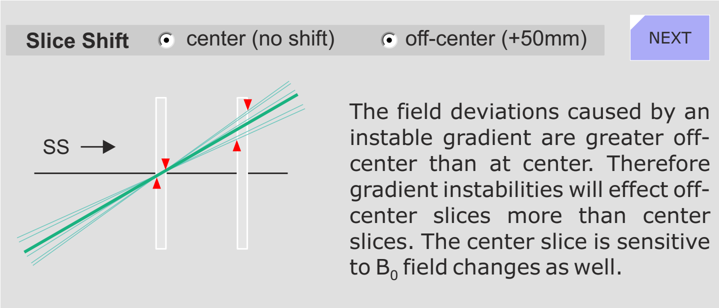
The spin echo sequence is more sensitive to RF instabilities because the echoes are produced by the 180° refocusing pulse.

Protocol GE

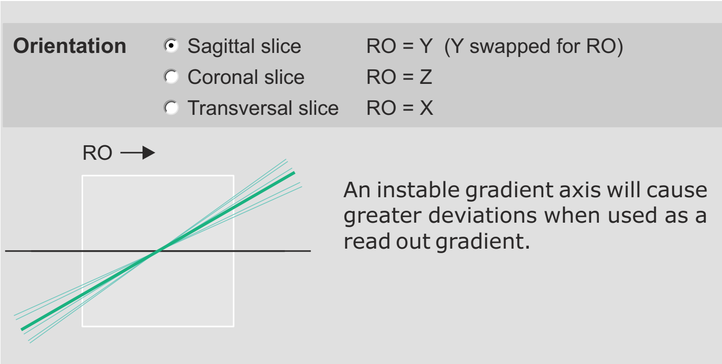


The gradient echo sequences are more sensitive to gradient instabilities since here the echoes are a result of gradient refocusing pulses.

The off-center measurements are also more sensitive to gradient instabilities then the center slices due to the enhanced effects of the gradient fields the further away from center the measurement is made.

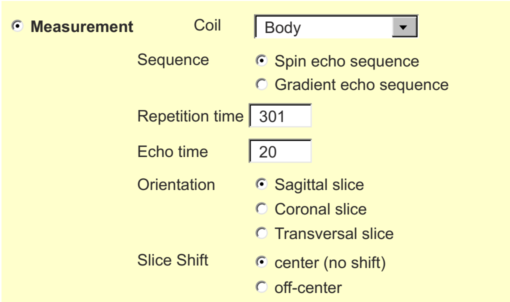


The orientation determines the role of each gradient axis. For example, lets assume there is an instability in the X gradient. The values for the sagittal orientation (X = slice selection) may be in spec while the spec for the transversal orientation (X = read out) could be out of spec.



Expert Mode

Expert Mode lets the user select either a Spin echo or Gradient echo sequence, modify the default parameters (slice shift of 0 and +50 mm, orientation and TR and TE values.

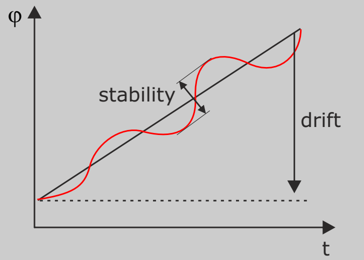


Evaluation

Amplitude Stability

The amplitude value in the column of maximum signal is displayed in the graphical output.

The phase shift of a **spin echo** is determined by the integral over the magnetic field from 90° to 180° pulse minus the integral from 180° pulse to echo:



$$\varphi = \int_{0}^{TE/2} \gamma B(t)dt - \int_{TE/2}^{TE} \gamma B(t)dt$$

For a constant field or a slowly varying field, both integrals cancel each other. However, for an oscillating field with a period of TE (20 ms = 1/50 Hz) this expression becomes maximum.

For the **gradient echo** sequence, the phase stability is evaluated by fitting a straight line to the phase data. Subtracting the value of the linear fit from the phase data results in the phase stability changes. The slope of the straight line indicates the linear phase drift.

Figure 241 *Stability Check Evaluation*

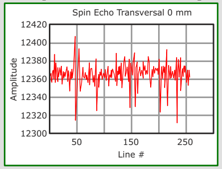
Results

Main Menu

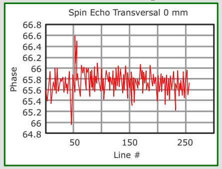
Spin Echo Sequence: Transversal Slice 0 mm

	Value	Low Spec	High Spec	Unit
Amplitude Range	0.456	0.000	2.000	%
Phase Range	1.721	0.000	4.000	deg
Average Peak Column	128.94			Cols
Peak Column Range	0.005	0.000	0.070	Cols

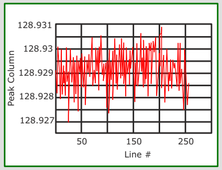
Amplitude Stability



Phase Stability



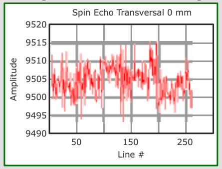
Peak Column



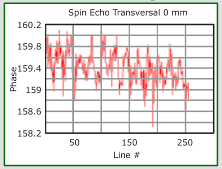
Spin Echo Sequence: Transversal Slice 50 mm

	Value	Low Spec	High Spec	Unit
Amplitude Range	0.235	0.000	2.000	%
Phase Range	1.959	0.000	4.000	deg
Average Peak Column	128.95			Cols
Peak Column Range	0.005	0.000	0.070	Cols

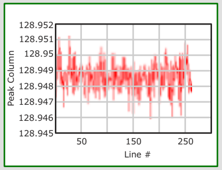
Amplitude Stability



Phase Stability



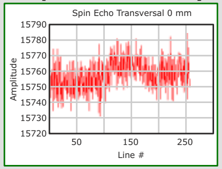
Peak Column



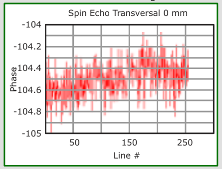
Gradient Echo Sequence: Transversal Slice 0 mm

	Value	Low Spec	High Spec	Unit
Amplitude Range	0.333	0.000	2.000	%
Phase Range	0.780	0.000	4.000	deg
Phase Drift	0.209	0.000	4.000	Cols
Average Peak Column	128.99			Cols
Peak Column Range	0.009	0.000	0.070	Cols

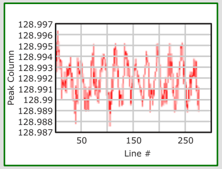
Amplitude Stability



Phase Stability



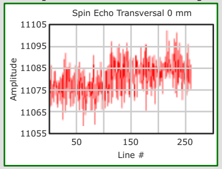
Peak Column



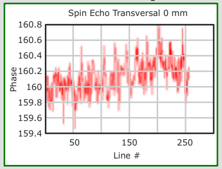
Gradient Echo Sequence: Transversal Slice 50 mm

	Value	Low Spec	High Spec	Unit
Amplitude Range	0.382	0.000	2.000	%
Phase Range	1.088	0.000	4.000	deg
Phase Drift	0.348	0.000	4.000	Cols
Average Peak Column	129.01			Cols
Peak Column Range	0.009	0.000	0.070	Cols

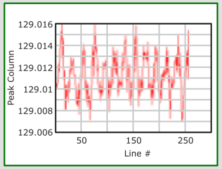
Amplitude Stability



Phase Stability



Peak Column



Fat Saturation

Fat saturation is a widely used feature to suppress the fat signal in MR images. There are various methods for doing this, the most common however is the spectral method. Fat protons precess at a frequency 3.4 ppm lower than water. By applying an RF pulse at this frequency, together with spoiling gradients, before each Fouier line the fat signal is deflected and will not attribute to the final MR signal. The Spectral fat saturation method requires very good homogeneity (1-2 ppm peak-peak) and a well defined RF pulse to prevent the water from being saturated as well. In addition, the RF-flip angle of the Fat Sat pulse should be about 90 degrees to get optimal results.

Measurement

First a reference image is made without saturation to determine the nominal signal level. The second measurement is performed with water saturation.

Evaluation

The normal image is analyzed for position and diameter. Then, a region of interest (80% of the phantom diameter) for both images is defined and the ratio of both signals is calculated point by point. To reduce noise at every point, a 3x3 average over neighbor points is performed. Point by point saturation ratios are calculated, resulting in a mean and a maximum value which are compared to specification.

Results

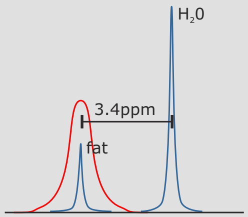
The images measured are loaded and displayed. Image windowing is done by clicking and dragging the mouse or by direct input of image window and center values.

The degree of Fat Sat mainly depends on the shim condition. As a rule, for a mean saturation ratio of 15%, the peak-peak homogeneity of the field has to better than 4ppm.

Figure 242 *Fat Saturation*

Main Menu

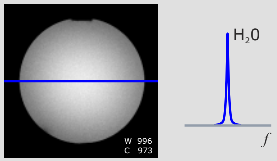
Measurement



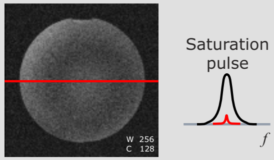
Normally, the saturation pulse is at the fat frequency. This measurement sets the saturation pulse frequency to water. If the magnet homogeneity is good (good shim, good eddy current compensation, good RF pulse selectivity) the result should be the same for fat.

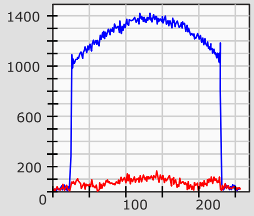
Result

Reference Image



Saturated Image





Saturation Ratio

	Mean				Max			
	Value	Low Spec	High Spec	Unit	Value	Low Spec	High Spec	Unit
Transversal	5.9	0.0	15.0	%	9.6	0.0	30.0	%

SAR Monitor Test

The purpose of this test is to verify that the SAR (Safe Absorption Ratio) check is activated. It is also tested if the pickup-coils detect a signal.

Measurement

A measurement with the service sequence gradsens is performed to ensure that the phantom (with loader) has been inserted and centered correctly. The SAR monitor test does not obtain a quantitative calibration of the SAR but tests that the SAR is switched on. However, the values retrieved will be displayed.

The following steps are performed:

- SW reset of previous values for pick-up coils and SAR value
- Measurement with the gradsens-sequence, evaluation of phantom position and type
- Analysis of SAR and the two pickup-coil values
- Display of measured values and the ratio of the two pickup-coil values

NOTE	Systems that are equipped with one receiver cassette only can not measure the pick-up coil signals. In that case, a corresponding message appears in the report.

Go to MAIN MENU

Synthesizer Check

The Synthesizer Check procedure is an important test to verify the proper operation of the NCOs residing on the PCI_TX and PCI_RX boards. It is used to validate the frequency and phase quality of the NCOs with respect to the accuracy of the slice position. The DDSs of the Synthesizer are not tested with this test.

Measurement

Refer to the diagram below.

When simultaneously transmitting and receiving, as is the case for all RF Test Tools, the phase and frequency of the TX-NCO and RX-NCO is the same and therefore any deviations will not be noticed. To test the NCO stability a sequence must be used with asynchronous behavior of the TX and RX NCO, that means one NCO is stepping phase and frequency while the other is fixed. For that reason different groups of NCO's are used when sending and receiving simultaneously, i.e. TX NCO is fix and RX-NCO is stepping.

In a first step the verification of the frequency and phase operation is performed using MR signals (nco sequence). An initial FID signal is measured which is used as a reference.

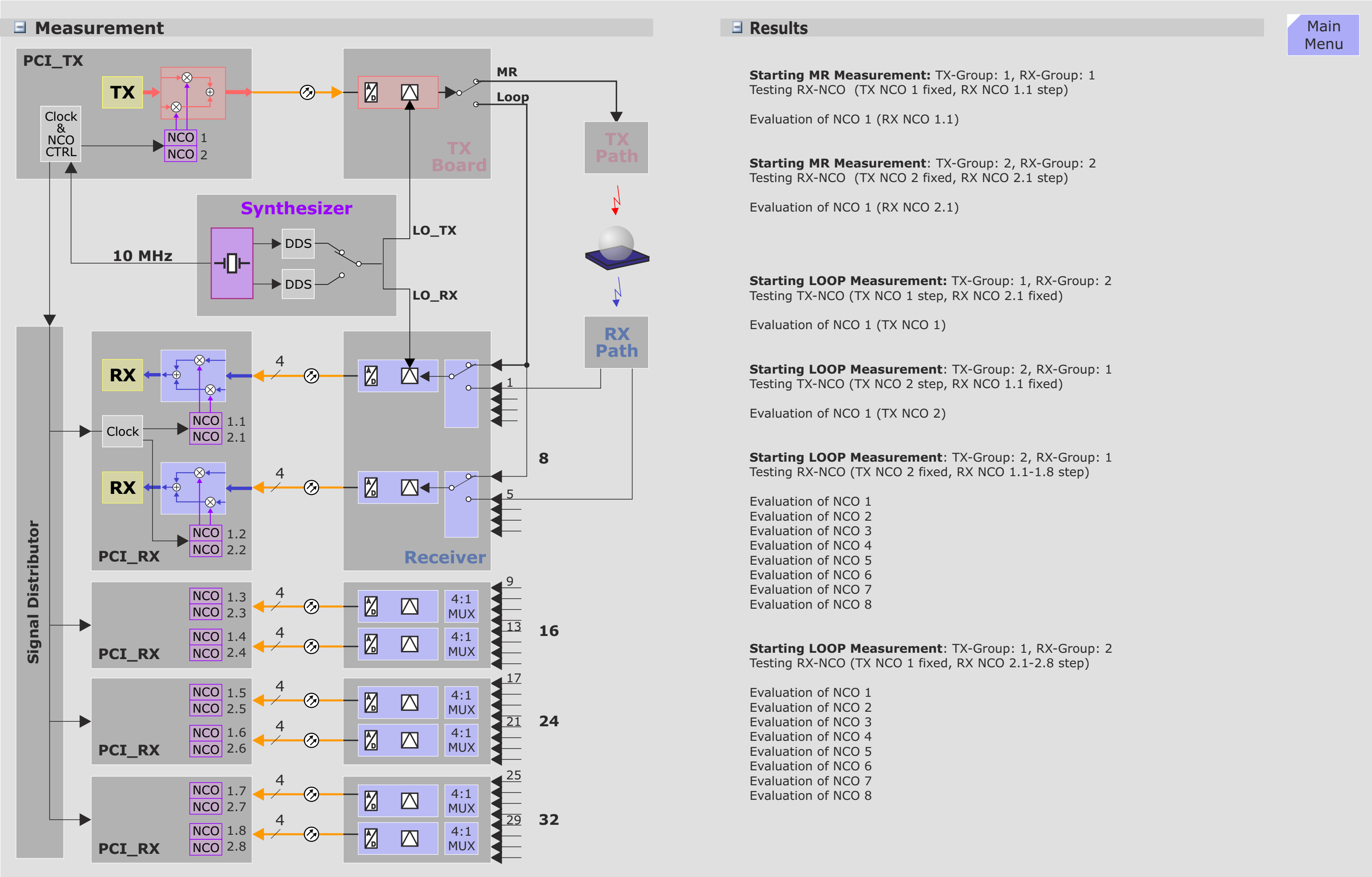
In one test, the reference signal is varied in frequency over the whole range of the MR system. A second test modifies the phase in fixed intervals. In this way the whole operating range of the oscillator can be tested. The test is performed for one RX-NCO from group 1 and one RX-NCO from group 2. So the two RX-NCO's are validated and can be used for further tests of the other NCO's.

In a second step loop-measurements are performed (nco_loop sequence) between the tested RX-NCO's and the TX-NCO's to test the function of the TX-NCO's.

In the further steps all other RX-NCO's are tested against the approved TX-NCO's by testing separately the group 1 RX-NCO's and group 2 RX-NCO's.

NOTE This test can determine deviations only in the NCOs residing on the PCI_TX and PCI_RX boards. The DDSs located on the Synthesizer are not tested with by procedure!

Figure 243 *NCO Test aka Synthesizer Check*



Stability_LongTerm Check

A new application of MR-Imaging is to make activities in the brain visible. For that purpose the patient will be exposed to a periodical optical, acoustical or other stimulation. During the exposition, a series of MR-images will be measured. Afterwards the images will be evaluated for changes of the signal intensity. The regions of the brain activated by the stimulation can be localized by a very small variation of signal intensity. These variations can easily be hidden by various instabilities of the system and/or the environment. Therefore the instability of the MR-system and interferences from environment must be below a specified level.

The Stability_LongTerm Check determines the sum of all instabilities while doing a phantom measurement. Typical causes of instabilities are:

- Local B0 field variation caused by temperature variation in the shim iron plates generate frequency drifts. The result is a virtual movement of the measured object during the scans.
- B1 field variations by instable RF produce image intensity variations.
- Gradient fields generate frequency and phase variations, causing also virtual movement of the object.
- Mechanical vibrations, e.g. by cold head, produce signal intensity variation by the movement of the measured object relatively to the magnetic iso-center.
- Movement of phantom fluid cause phase errors.

Measurement

NOTE	Between phantom positioning and measurement start wait at least 15 min, since even small movements of phantom liquid will affect measurement results.

The measurement is performed with the 8 Channel Head Matrix coil and the large bottle phantom (7.3 l).

Before beginning a warm-up scan is performed to achieve thermal equilibrium of the hardware components.

Afterwards two measurements (EPI_FID sequence) will be made with a s of 512 measurements and 11 slices:

- first measurement with a FLIP ANGLE of 30° (evaluation of B1 field stability)
- second with a FLIP ANGEL of 90° (minimization of unstable RF, detection of B0 and gradient-like interferences).

Evaluation

The following graphical and numerical evaluations will be performed:

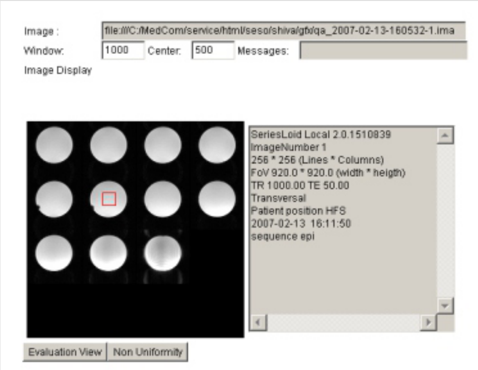
- Mean values of a 15x15 ROI related to the mean value of all measurements as function of image number
- Standard Deviation of a 15x15 ROI mean values (linear and logarithmic plot)
- Center position in x and y direction of phantom, dependent of image number (Expert mode only)
- Measurement protocol values
- Statistics of Mean values for ROI size of 25x25:
  - Mean Image Intensity
  - Peak to Peak Variation
  - Relative Peak to Peak Variation
  - Standard Deviation
  - Total relative linear Drift
  - Standard Deviation from linear Fit
  - Peak to Peak Deviation from linear Fit
  - Total Relative Quadratic Drift
  - Standard Deviation from Quadratic Fit
  - Peak to Peak Deviation from Quadratic Fit
- Image quality parameters such as SNR and Ghosting
- Statistics of Phantom Movement (Expert mode only)

Figure 244 *Long Term Stability Check*

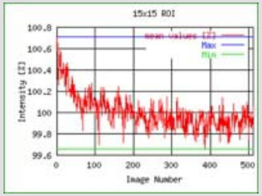
Measurement

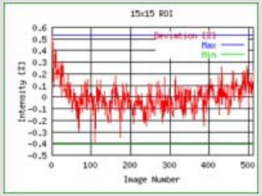
Flip Angle = 30°

First image of series

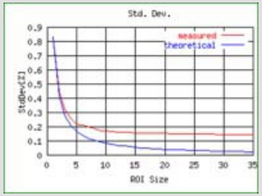


Mean of ROI porportional to mean deviation from linear fit

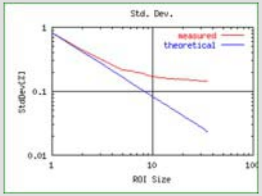




Std. Dev. of ROI Mean values (linear)



Std. Dev. of ROI Mean values (log)



Results

Main Menu

Protocol Values

	Value	Unit
Multi Slice	11 slices, 4x4 mosaic	
TR	1000	ms
TE	50	ms
FOV	230	mm
Slice Thickness	5	mm
Flip Angle	30	deg
No of measurements	512	
No of prep.scans	5	
Image Orientation	Transversal	

	15x15 ROI, Flip Angle: 30 deg				25x25 ROI, Flip Angle: 30 deg			
	Value	Low Spec	High Spec	Unit	Value	Low Spec	High Spec	Unit
Mean Image Intensity	829.520				828.902			
Variation Peak-Peak	8.653				7.274			
rel. Variation Peak-Peak	1.049			%	0.883			%
Std.Dev.	0.158			%	0.149			%
total rel. linear Drift	-0.356	-0.600	0.600	%	-0.349	-0.600	0.600	%
Std.Dev. from lin. Fit	0.119	0.000	0.330	%	0.110	0.000	0.300	%
Peak-Peak Dev. from lin. Fit	0.935	0.000	1.650	%	0.777	0.000	1.500	%

Field Stability

This procedure is used to measure magnet field changes. To eliminate influences by the gradients and RF the FID is used.

Measurement

A total of 512 FIDs are measured over a 154 second period (repetition time of 301 ms). From every FID the phase over time is calculated and a linear fit is done, the slope giving the frequency.

The time range of the fit should be long to get a high accuracy but is usually limited by the length of the FID. A good compromise is 20ms, which averages over 50Hz line hum which is usually of no interest in this measurement.

Evaluation

To replace the integral, it is assumed that the field B(t) does not change much during sampling of the FID. So the field can be calculated directly from the phase at time t. However, because of hardware imperfections it is better to take the slope of the phase over time which also gives the field.

The result of the field measurement is the field (=frequency) over the measurement time. As a measure of quality the linear drift over 10 minutes (=typical measurement time of an imaging sequence) and the maximum deviation from this linear drift are taken. When the measurement time is different from 10 minutes, the drift is corrected for 10 minutes by multiplying with the ratio (10min/actual measurement time).

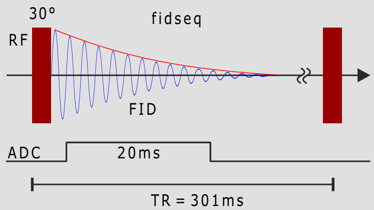
The drift over 10min should not exceed the pixel bandwidth of low bandwidth sequence (e.g. 20Hz). The max deviation value is important for gradient echo sequences to avoid smearing. To be able to use long echo times it should be typically less than 2Hz.

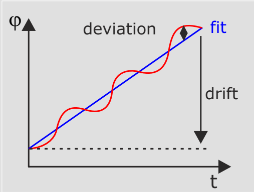
Figure 245 *Field Stability*

Measurement

Main Menu

Field Stability





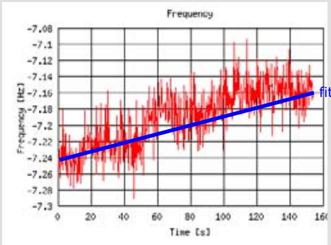
$$\varphi(t) = \gamma \int_0^t B(t)dt \approx \gamma B \cdot t$$

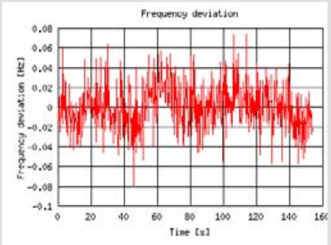
γ is the gyro magnetic ratio of the proton
B(t) = time dependent magnetic field
t = 20ms measured every 301 ms.

Results

Frequency Check

	Value	Low Spec	High Spec	Unit
Frequency Drift	0.39	-4.00	4.00	Hz/10min
Maximum Deviation	0.08	0.00	2.00	Hz





Gradient Risetime Check

The Gradient Rise Time Check measures the minimal gradient rise time or the so-called “Slew Rate”.

Measurement

The measurement uses a spin-echo EPI sequence; the tested gradient channel has phase-encoding as well as readout functionality. In the readout interval, develop five echoes because of the bipolar triangle gradient pulses. These echoes should appear according to the pre-dephasing exactly at the pulse spikes. During the measurement, the pulse amplitudes run the range from -Gmax to +Gmax.

Simultaneously with the pulse amplitudes, the ascent of the pulse ramp (with constant pulse ramp time) changes and determines the limits of the gradient system.

If there is a deviation of the echo position from the nominal position, the required slew rate could not be reached.

The limits can be determined and calculated from the raw data (representation of magnitude with corresponding windowing).

Sequence of procedures:

- Verification check of the used phantom
- Gradient Risetime measurement for all three gradient axes
- Evaluation of the raw data image and calculation of gradient rise time
- Numerical and graphical output

Evaluation

The following output data will be shown in the report:

- Graphics of echo maximum vs. gradient slew rate, echo 1 -5
- Statistics of measured values against specifications
- Y/Z/X- Gradient Rise Time Results
- Y/Z/X Gradient Rise Time Multiple Echo Output (raw data image)

Figure 246 *Gradient Risetime Check*

Gradient Risetime Check

Main Menu

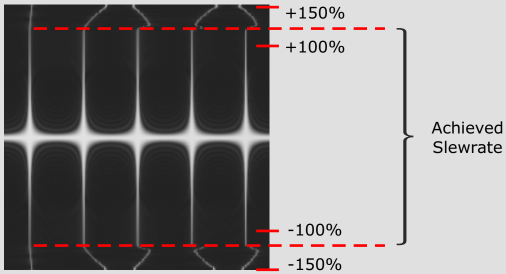
Results

Y Gradient Risetime Results

	Slew Rate		
	Value	Low Spec	Unit
Echo 1	118.06	100.00	%
Echo 2	118.06	100.00	%
Echo 3	116.90	100.00	%
Echo 4	115.74	100.00	%
Echo 5	115.74	100.00	%
Echo 6	115.74	100.00	%
Echo 7	115.74	100.00	%
Echo 8	115.74	100.00	%
Echo 9	115.74	100.00	%
Echo 10	115.74	100.00	%

Y-Gradient strength slew rate achieved is 115.74% of specified value (mean value of the lowest two values of all echoes)

Y-Gradient - Multiple Echo Output



Temperature Sensor Test

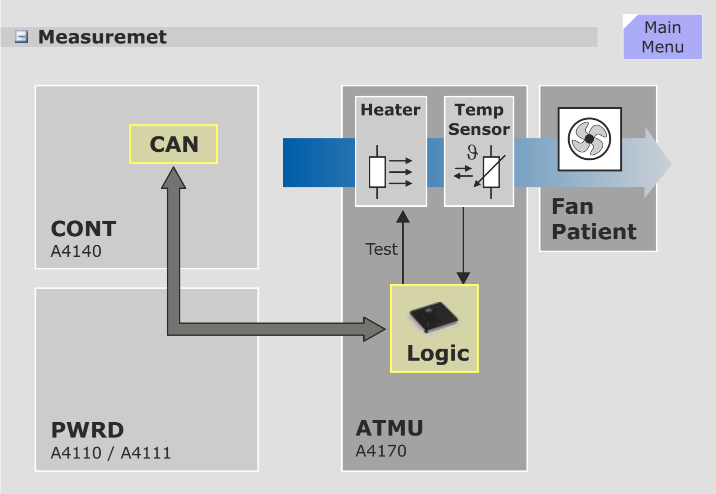
During every MR examination the Specific Absorption Rate of the body tissue has to be monitored carefully and checked against the valid country-specific SAR guidelines. In addition it is important that the temperature inside the bore of the MR scanner lies inside specified ranges to allow an efficient cooling of the patient. The Air Temperature Measurement Unit (ATMU) of the Patient Table is responsible for that task and can be tested with the Temperature Sensor Test.

Measurement

The procedure works in the following way:

- Measurement of initial temperature and check if it is within reasonable limits
- A sensor heating element is activated until either a 5 degree temperature rise is measured or 30 seconds have passed.
- Output a pass/fail message

Figure 247 *Temperature Sensor Test*



Results

Measured Temperatures

	Value	Unit
Before Test	23.0	C
After Test	29.0	C
Change	6.0	C

Note: Do not repeat this test in the next 10-15 minutes to allow sensor to return to ambient temperature.

Section

12 Dot Option

Overview

To provide the Dot engine functions the **NUMARIS VD-line** software is required which is based on the daVinci system control architecture. This in turn requires new hardware.

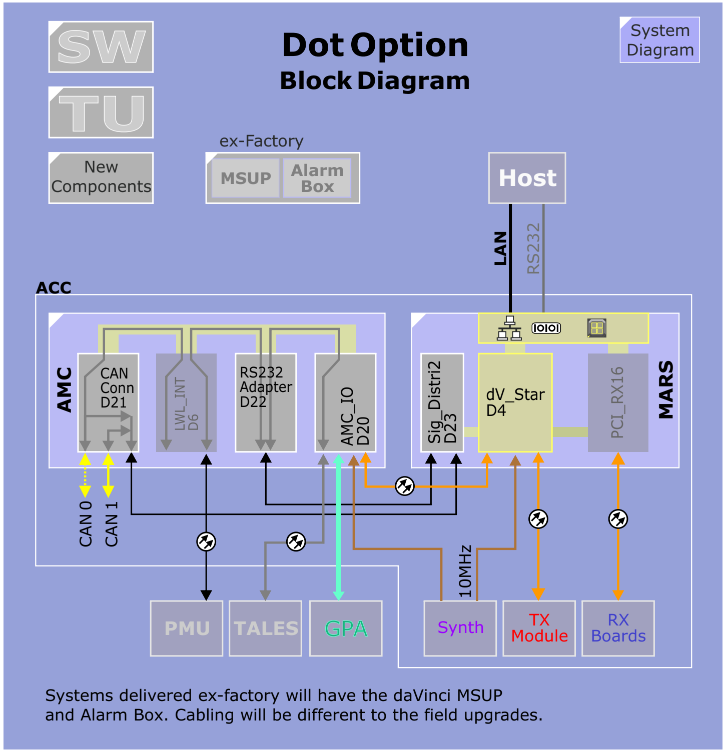
For existing Avanto customers this additional hardware is available as an upgrade kit (**field upgrade**).

For new purchases the hardware will be pre-installed at the factory (**ex-Factory**).

There are, however, differences between these two Dot option implementations: the ex-Factory version includes the new RoHS compatible MSUP K2306 and associated Alarm Box. These components require changes to some cables. These changes are described in the Dot ex-factory section below

NOTE This section describes only the differences to the MAGNETOM Avanto systems.

Figure 248 *Dot Option Block Diagram*



Hardware

New components for both versions of the Dot option:
- **MARS**, including:
  - dV_Star
  - Signal Distributor
- **AMC_IO** D20
- **CAN_Connector** D21
- **RS232_Adapter** D22
- Maintenance-free (sealed) **phantoms** and color-coded **holders**

Additional components and changes of the ex-Factory version:
- **MSUP**
- **Alarm Box**
- All cables to/from the MSUP and Alarm Box
- Internal ACC cabling !!!
  - W3560 - major changes to the internal ACC wiring.

The following list summarizes the upgrade components :

New	Replaces
MARS	MPCU, Imager
dV_STAR D4	PCI_TX, PCI_MON, PCI_CAN
AMC_IO D20	part of the PCI_TX (GPA interface and dynamic control signals)
CAN_Connector D21	provides the CAN bus connections. It only has a signal routing function, it has no electronics.
RS232-Adapter D22	It only has a signal routing function, it has no electronics.
Sig-Distributor D23	acts as an interface between dV_Star and the CAN_Connector and RS232_Adapter

Figure 249 *Dot Option Components*

MARS

The MARS is outwardly identical to the MARS 2 of daVinci. It is connected directly to the Host via the LAN.

The LAN SWITCH HAS BEEN REMOVED!

Function

It performs the roles of both the Imager and MPCU.

The MARS is available in these hardware configurations:

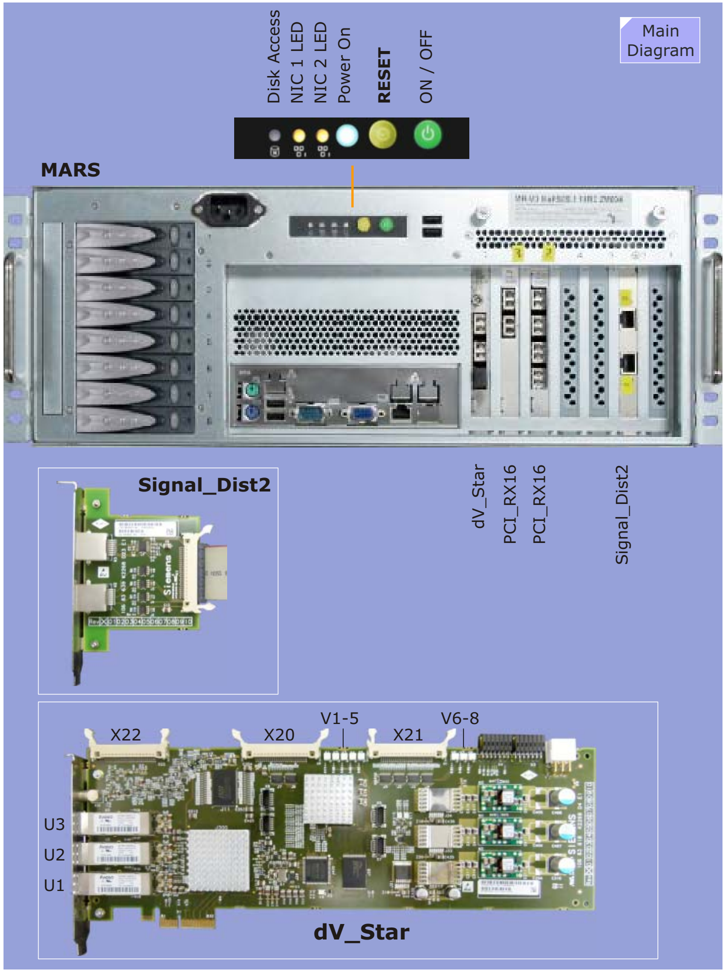
	18 Channel	32 Channel
CPU	1x Intel 64bit Xeon QuadCore 3.1GHz	
Memory	32 GB	
Hard Disk	4	5
Front-side Connections		
ETH 0	1000T connection to Host	
RS232	boot messages to Host	
PCIe Slots		
7	dV_Star	
6	PCI_RX16-16	PCI_RX16-16
5	PCI_RX16-8	PCI_RX16-16
3	Signal_Distributor 2	

The MARS is identical in both Avanto and Verio upgrade packages.

FRUs

See Spare Parts Catalog.

Figure 250 *MARS*



dV_Star

Overview

The dV_Star combines the functions of the PCI_TX, PCI_MON and PCI _CAN on a single PCIe slot board. Main components are the functional FPGA and a DSP. In essence the dV_Star is the daVinci system control on a single PCB. The ISO-Ring is realized on chip.

Function

The dV_Star provides the following functions:

- PCIe communication to MARS
- Sequence control
- Instruction handling and communication to transmitter/ modulator, GPA and PCI_RX
- DSP communication for PALI/STIMO and gradient calculation
- CAN communication
- PDAU communication

Special Boot up tests:

- LWL OK - check whether light is received
- TALES OK - check reference level
- DSP OK - ping DSP successfully

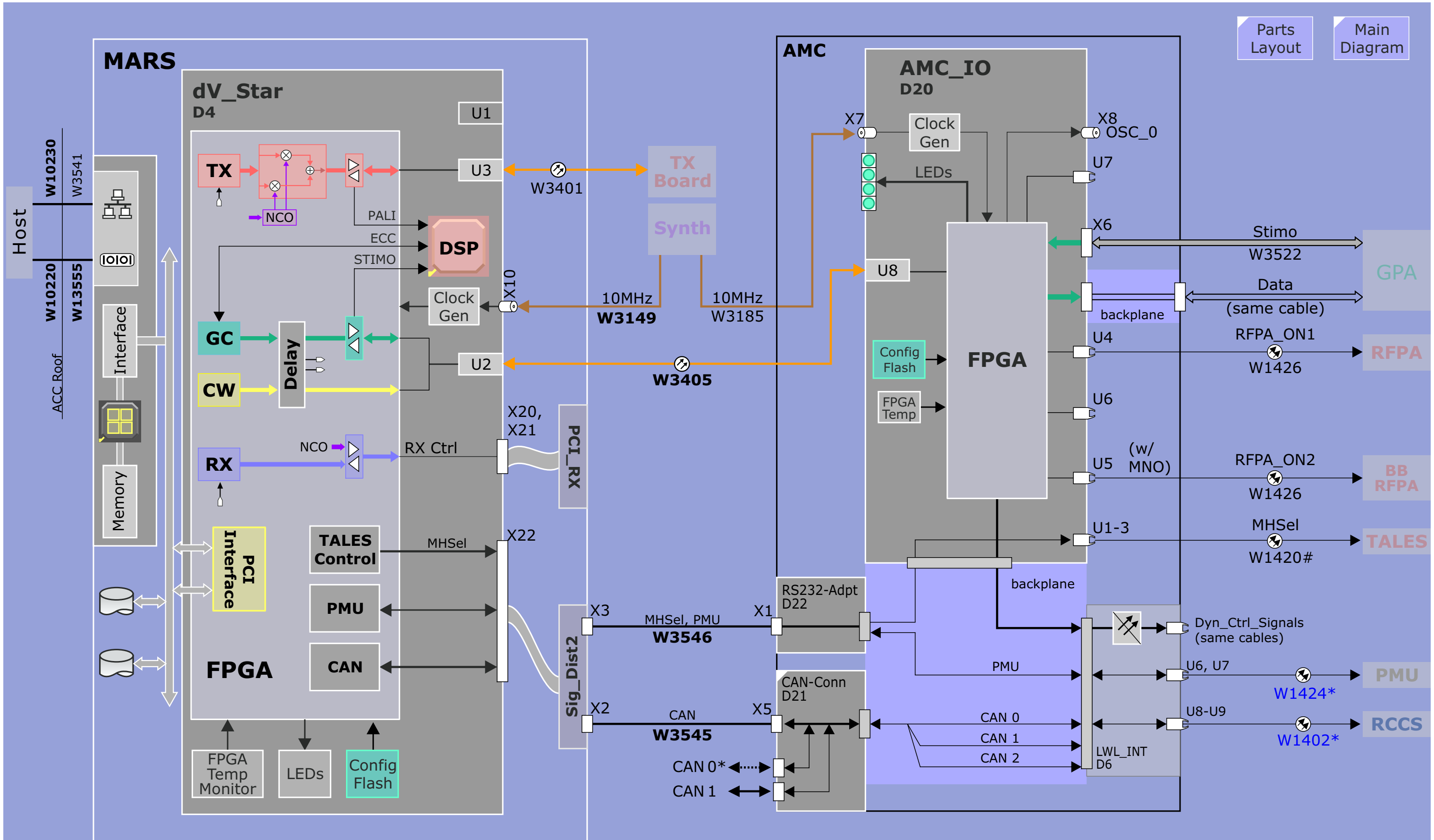
LEDs

There are 13 LEDs on board, only visible when MARS cover is removed. **V1** (heartbeat) is of service relevance and indicates the FPGA has been properly configured and is working. There are 6 LEDs which can be red, these of course should not be on except maybe during booting.

Outputs

Connector	
U1	Not used
U2	GPA and sequence timing and control signals to AMC_IO
U3	Digital RF pulses and RF control signals to Transmitter
X20, X21	RX control to PCI_RX boards
X22	TALES control, PMU and CAN signals to AMC_IO via Signal_Distributor

Figure 251 *Hardware Overview*



Only signals pertaining to the upgrade are shown in this diagram unless otherwise noted.

* these cables have connections that deviate between field and ex-factory upgrades
\# this cable is the same but has a different part number

AMC_IO

Overview

The AMC_IO is actually an extension of the dV_Star. It is a solution to interface the dV_Star which now supplies all the signals once provided by the PCI_TX, PCI_MON or PCI_CAN to the existing cabling. This is also the purpose of the RS232_Adapter and CAN_Connector.

Function

FPGA

There is an FPGA on the board which provides these functions:

- decode the serial gradient pulse data from the dV_Star into a parallel data bus (labelled Data in the diagram) for the GPA DAC
- It also does the opposite (parallel to serial conversion) for the digitized gradient pulse data coming back from the GPA (labelled STIMO in the diagram).
- decodes the sequence timing signals from dV_Star and sends them to the LWL_INT for distribution.

FPGA Temperature

The AMC_IO has one temperature sensor that checks the temperature of the FPGA.

LEDs

LED	Color	Description
V1		FPGA is successfully configured (Config_Done)
V2		Clock is okay (TX-PLL is locked)
V3		Communication line to dV_Star is okay (RX-PLL is locked)
V4		Communication line to dV_Star is okay (RX-Freq is locked)

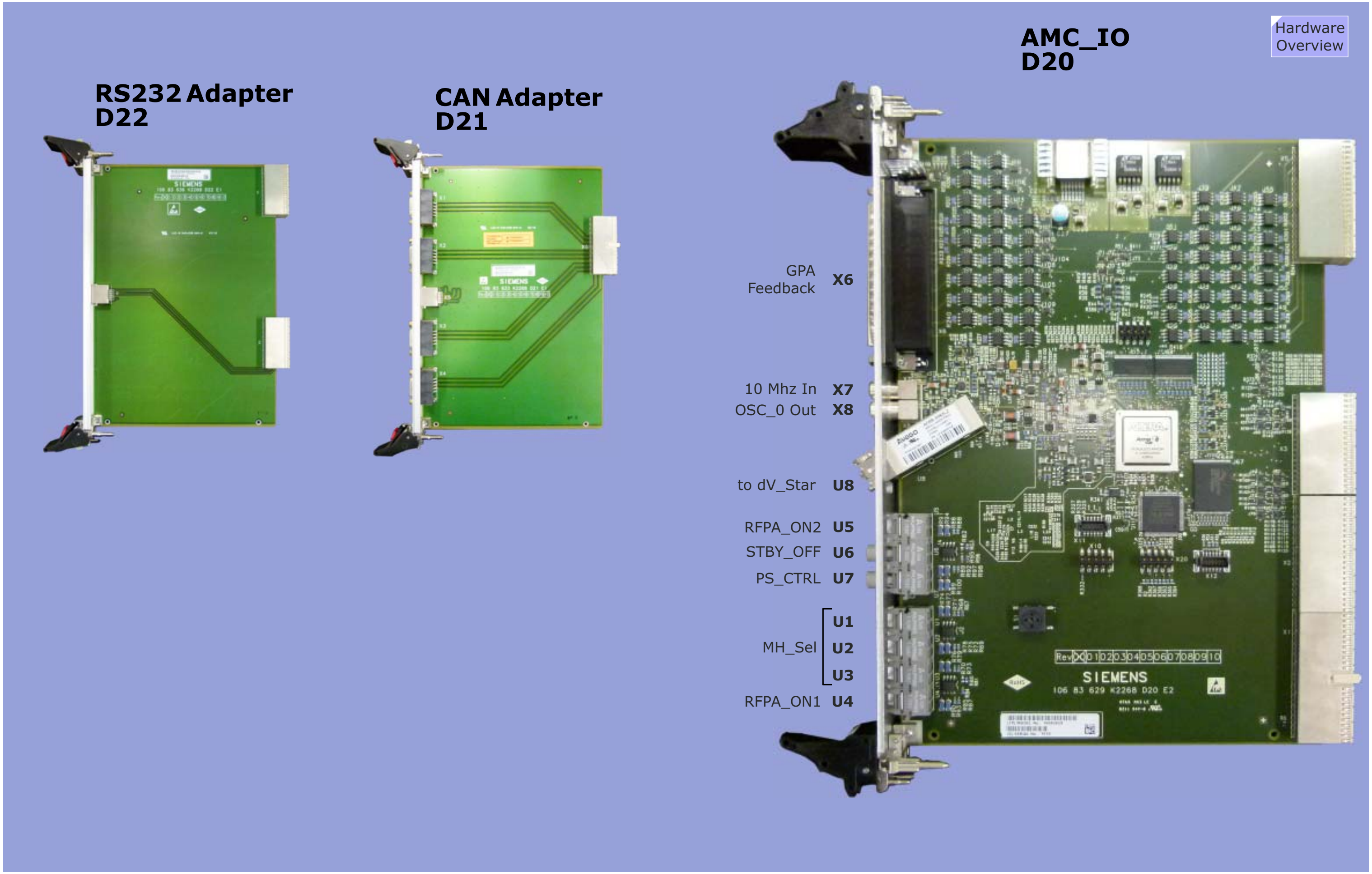
Inputs

Connector	Description
X6	Connection to the D60 Service board in the GPA for the feedback to the stimulation monitor.
X7	10 MHz clock for the FPGA. This requires one of the new cables.
U8	Main input from dV_Star using a high-speed glass-fiber link.

Outputs

Connector	
U1	MH_Sel signals to the TALES for address selection of the 6 forward and reflected RF values required by the SAR monitor.
U2	
U3	
U4	RFPA_ON signal for the main RF amplifier
U5	RFPA_ON signal for the BB RFPA (MNO)
U6	Standby_Off signal for Astex (or tube) RFPA (Verio)
U7	PS_CTRL, together with the PS_FB signal from the LWL_INT, control the True Form/CP state of the BCCS for the Verio system
X8	oscilloscope trigger

Figure 252 *Parts Layout of new components in AMC*



Dot ex-Factory

Factory assembled Avanto Dot systems will have the daVinci Magnet Supervision K2306 and Alarm Box. The cabling differences to the field upgrade version are shown on the next two diagrams. You will have to refer to the Aera/Skyra functional description for a description of these components.

The daVinci MSUP has different interfaces and an additional interface for the compressor requiring several changes in the cabling. The following two diagrams detail these changes.

CAN Interface

Because the daVinci MSUP requires a connection to the **active** CAN bus CAN1, the existing CAN1 output of the LWL_INT (U10/U11) that went to the MDSD over new cable W1401.

An additional cable W5407 connects the MDSD to the MSUP for CAN connectivity.

To connect the RCCS, RFIS and PTAB to the CAN0 bus the spare optical CAN0 output of the LWL_INT (U8/U9), unused until now, is routed to the RCCS using the new cable W1402.

Magnet and Compressor Interface

Figure 254 shows the connections to the MSUP, Alarm Box and Compressor (MREF). The connections and cabling are identical to daVinci. This, however, has consequences to the internal wiring of the ACC cabinet, W3560. It is significantly different to the Dot upgrade version. Please refer to the schematics for details.

Figure 253 *CAN Topology Dot ex-Factory*

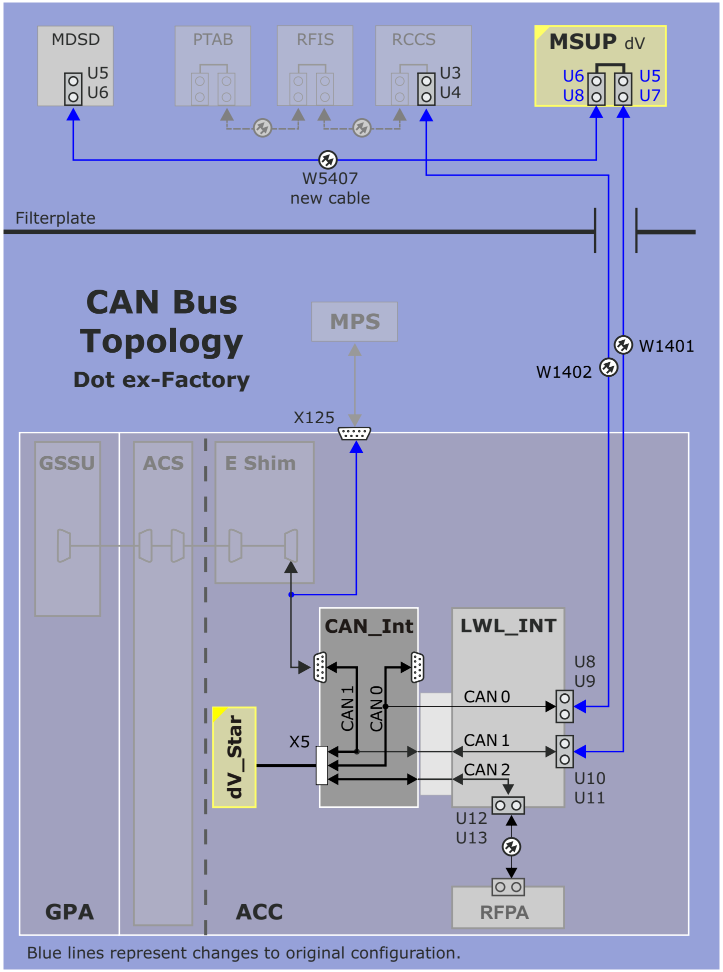
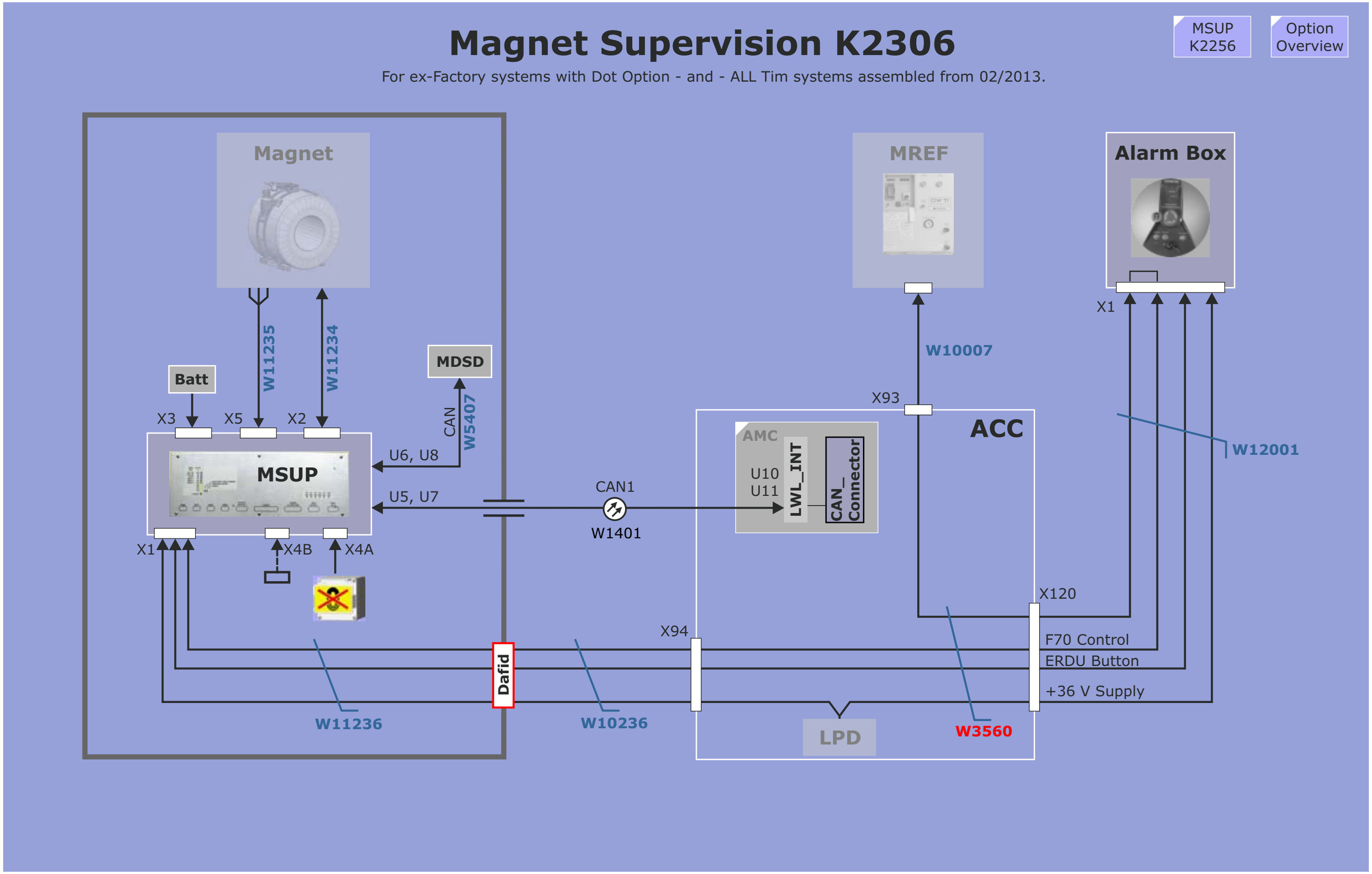


Figure 254 *Dot ex-Factory - Magnet Supervision K2306*



Software

For the Dot upgrade the NUMARIS VD_ software is installed. This version is the same version as the Aera/Skyra systems and as such the service relevant features of this software version are the same and are described in the Aera/Skyra Functional Description.

The main differences from VB_ software are:

- SeSo UI - addition of the **Coils** button
- Magnet and Cooling - the masks correspond to the new MSUP
- TuneUp - tune up steps required by the Avanto hardware components:
  - Tuning Calibration
  - RF Characteristic curve
  - RF Characteristic curve LC

Go back to MAIN MENU

Tune Up

The Tune Up for Avanto Dot with the **VD_** software line is for the most part identical to the Aera and Skyra Tune Up. To be backwards compatible with the Avanto hardware the following steps were included (i.e., these steps are not found on other VD-line systems):

- Tuning Calibration
- RF Characteristic
- RF Characteristic LC

NOTE The report outputs for these procedure are the same as previous, refer to te Tune Up section in this document for details.

The VD-line Tune up procedures are performed in the following sequence:

- Rx Gain Calibration
- Tuning Calibration
- BC Tuning
- RF Characteristic
- RF Characteristic LC
- Gradient Regulator
- Light Marker
- Phantom Shim
- Body Coil Power Losses (CPL)
- Cross Term Compensation (CTC)
- Eddy Current Compensation (ECC)
- Gradient Delay
- Gradient Sensitivity
- BC Image Brightness
- Dynamic Field Map

The observant reader will notice the subtle changes to VB-line TuneUp. The RX Gain calibration is at the top of the list (is last in VB software), and the Dynamic Field Map procedure has been added. As already mentioned all other procedures are functionaly the same, although a comparison of the VB and VD reports will reveal minor changes to some of the report graphics.

NOTE The reader is refered to the Area/Skyra Functional Description for details.

Phantoms and Supports

The VD-line tune up procedures have been optimized for use with new phantoms.

- Large 240 mm spherical **oil** phantom
- Small 170 mm spherical water phantom
- Image Orientation water phantom (small bottle)

The phantoms are hermetically sealed and thus maintenance free.

To adapt the various bore sizes (60cm, 70cm) the phantom holders have been color coded. The phantom supports for is **red-blue** in color.

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Section

13 Service Tools

Introduction

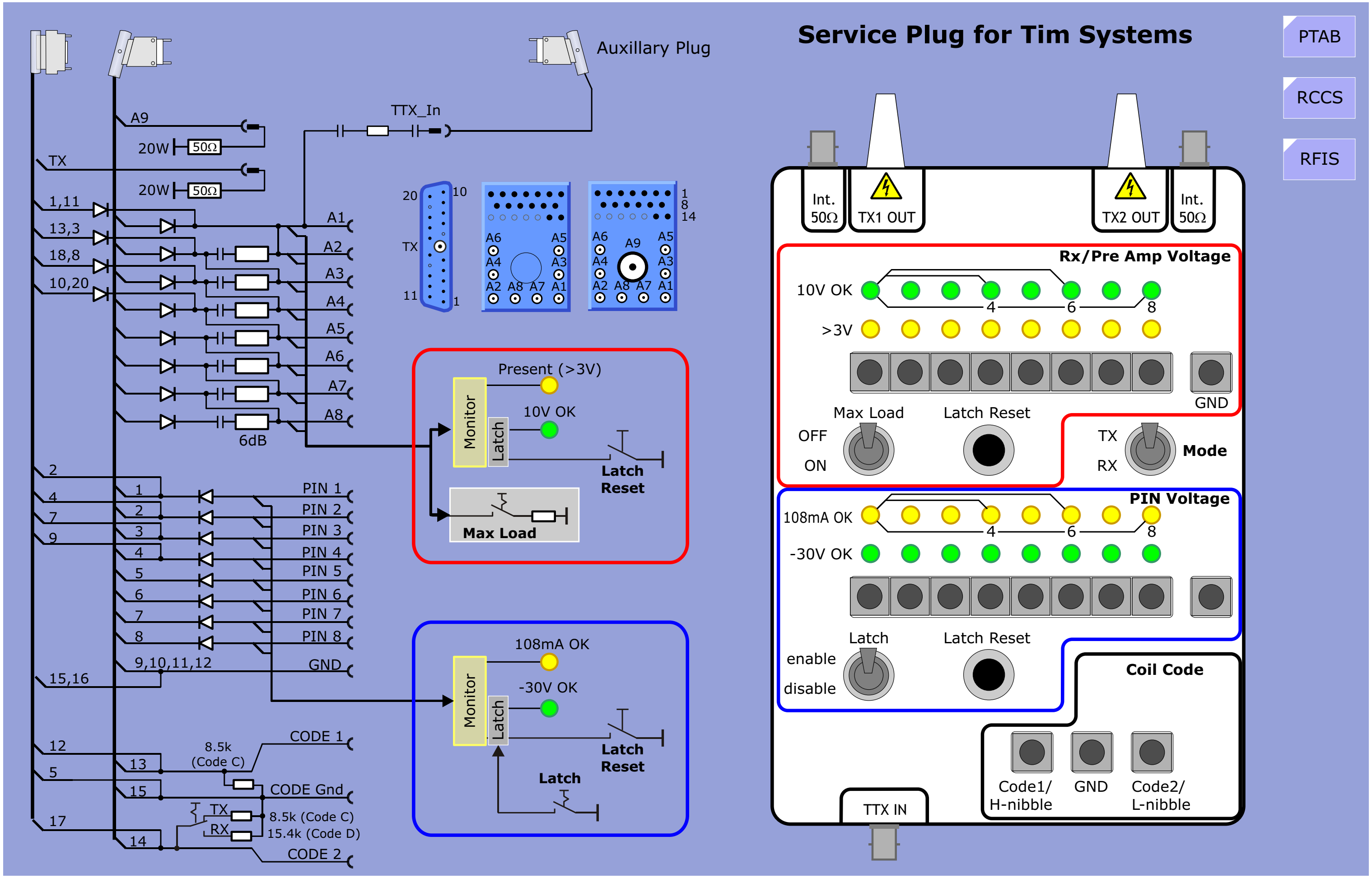
This section provides a functional description for any service tools having electronic or mechanical functions in and of themselves.

These include:

- Service Plug
- Helium Service Syphon Kit
- MSUP Display
- Magnet Power Supply
- Array Shim Device

Go back to System Diagram

Figure 255 *Service Plug Block Diagram*



Helium Service Syphon Kit

Due to the no boil-off concept, a Helium Fill Syphon is not standard (except for mobile systems). If a refilling is necessary (e.g. after Cold Head service), an adaptor - the service syphon kit - provides access into the magnet turret.

The Helium Service Syphon Kit is used for helium filling on all 4 K magnets and is compatible to the existing dewar syphon hardware.

Table 1 *Service Syphon Use for OR105/OR122 Magnets*

	130*mm leg	190*mm leg	End Pieces
Top Fill	2	N/A	parts 6 and 7
Bottom fill	2	1	part 8

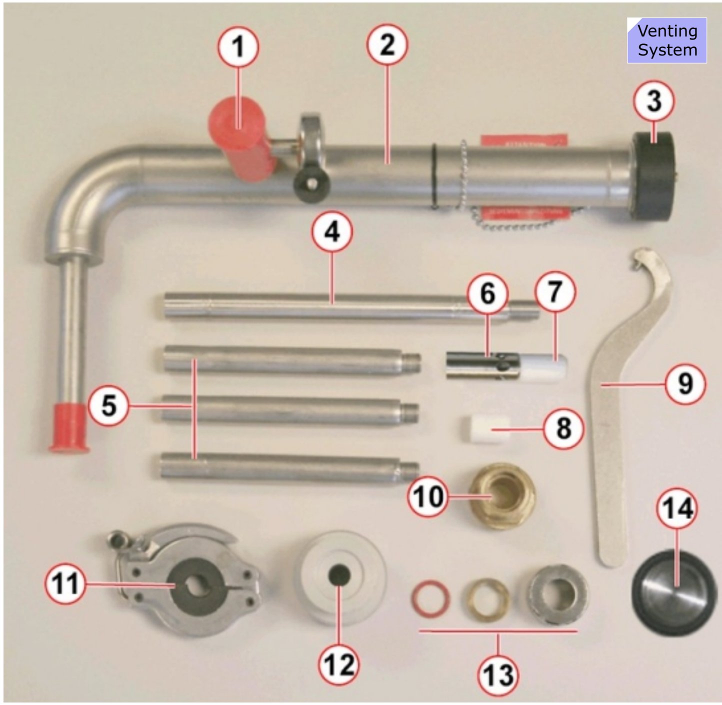
The syphon diffuser should optimally be 50-80 mm above the syphon cone for top filling.

Two fill configurations are possible:

- **Top-Fill** - This is the normal helium fill procedure configuration when the magnet is LHe-filled under field, during standard service or routine maintenance.
- **Bottom-Fill** - This fill procedure must be used when the magnet level is reading zero percent, or the magnet temperatures have risen above helium temperature (check Ceramic Carbon Resistor (CCR) values. It will avoid unnecessary helium loss and fill time. Bottom filling is required only in certain circumstances: after a quench or long transportation times.

NOTE The service syphon kit, part no: 10126651 is a service tool. To ensure that the LHe-filling procedure is performed correctly, refer to Installation>Start-up.

Figure 256 *Helium Service Syphon Kit*



1) Vacuum valve
2) Service Syphon assembly
3) Syphon end cap
4) 190 mm extension leg (1 x)
5) 130 mm extension legs (3 x)
6) 6 hole de-ice and helium fill diffuser tip (top fill)
7) PTFE de-ice extension tip (top fill)
8) 22 mm PTFE seal (bottom fill)
9) Syphon "C" spanner/wrench
10) Syphon adaptor bush
11) Syphon leg support clamp
12) Nitrogen fill adaptor and O-ring seal
13) Syphon ring nut, brass syphon flange, syphon O-ring seal
14) NW25 flow restrictor

MSUP Hand Display

General

The MSUP Display is a hand held monitoring aid that can be connected to the MSUP (X9) to read out the magnet sensor values. In addition, LHe-level measurement, EIS-Reset and Pressure Heater operation can be activated by hand. A full list of all values is given in “MSUP Display - displayed values”, below.

NOTE The MSUP Display must be disconnected during normal operation to avoid image artefacts.

Switching on MSUP Display

- Connect the Display Unit to connector X9 on the MSUP
- Ensure that the +36 V MSUP supply voltage is present
- Press the "SAMPLE" and the "DISPLAY" button

Operations

To initiate a LHe-level measurement, Battery Test and EIS Reset:

- Press the "SAMPLE" button on the unit

Scroll through the parameters:

- Pressing the "DISPLAY" button repeatedly

For Battery Test and EIS Reset the +36 V MSUP supply voltage must be present. The parameters are presented in a fixed cycle, so repeated pressing of the DISPLAY button is required to display all available parameters. A (W) or (A) will be displayed with the parameter reading to indicate a Warning or Alarm situation.

Figure 257 *MSUP Hand Display*

NOTE If the +36 V MSUP voltage is not present, the display of temperature values and sampling of LHe-level is possible due to MSUP battery backup. EIS Reset, Battery Test and Pressure Heater will not work in this mode.

For some parameters a control function is available (e.g. Pressure Heater). That function may be toggled ON and OFF by pressing the SAMPLE button.

MSUP Display - displayed values

1. In this instance "A" means Probe A - not "Alarm"

2. CCR 4 will be displayed in temp (Kelvin) or resistance (Ohms), depending on the MSUP personality.

	Parameter	Spec. OR98 / OR99/103
1	He level (Press sample to measure)	A1. 40% - 99%
2	Battery volts	25.9 V ON CHARGE
3	50K link, bore (Kelvin)	40 k (link), 47 k (bore)
4	Carbon Resistor 1, 2 (Ohms) CCR 1, 2 (Ohms)	1200 Ohms (1, 2)
	NOTE: On newer systems Ceramic Resistors are used with different resistance values. Typical values @ 4.2 k: 3000R 3000R	
5	Carbon Resistor 3, 4 (Ohms) CCR 3, 4 (Ohms), CCR 4 (Kelvin)[2]	1200 Ohms (3, 4)
	NOTE: On newer systems Ceramic Resistors are used with different resistance values. Typical values @ 4.2 k: 3000R 3000R	
6	Turret (FCL)1, 2 (Kelvin)	50 k (1), 52 k (2)
7	Switch Heater (Ohms, status)	130 Ohms, Off
8	Quench heaters 1, 2 (Ohms)	22.5 Ohms, 22.5 Ohms
9	Cold Head (K)	40 k
10	ERDU Buttons (status)	OK
11	Magnet pressure (psiA)	15.30 psiA
12	Pressure heater (Off/On, %,) (Press Sample to switch on, 50min time out)	Off, 20 % (normal operation) On, 100 % (manually activated)
13	Pressure heater (average power over the last 4 hours. Reboot scanner will reset last value!)	0.5 - 0.8 Watts
14	EIS (Off, Sample to switch On, 60min time out)	Off (normal operation) On (activated)
15	Self test	Pass
16	Compressor status (On/Off)	On
17	LVQD (MSUP 2657B only)	LVQD WAITING TRIGGER
-	Date and time	Date, Time
-	Software part number and version	e.g. 551-360 VA05K

Switching OFF MSUP Display

Disconnect the unit’s cable at connector X9 on the MSUP.

NOTE If the +36 V MSUP supply voltage is not present, the MSUP Display will switch off automatically after 2 minutes to preserve the MSUP battery power.

Magnet Power Supply 3600

Overview

The Magnet Power Supply (MPS 3600) is an air-cooled, portable service tool used to ramp up (energize) and ramp down (de-energize) the magnet for start-up and service purposes.

The MPS is software controlled requiring a laptop or computer (the Host) which will be connected to the MPS via a RS232 serial cable, included with the supply. For ramping the MPS needs to communicate with the Magnet Supervision Unit requiring an additional cable to connect to the CAN bus of the MR system. for line power supply, and for connecting the magnet coil via ramp cables.

The MPS consists of:

- MPS 3600
- Line power connection cable
- **Ramp cables** - Delivered with the system (or extension kit where required)
- **RS 232 connection cable**
- CAN bus connection cable
- Safety Manual

Physical Description

The MPS is enclosed in a robust blue shipping case, mounted on a trolley. The trolley has wheels to enable movement when required, but can be easily lowered on to skids when in position.

Removal of the lid of the shipping case exposes the working face of the MPS, enabling all the connections to be made and monitoring of local indicators to take place.

The MPS may be lifted clear of the trolley, if required, but care must be exercised as it weighs 80 kg (176 lbs).

The long sides of the MPS have open slot grills to allow the flow of cooling air.

Servicing

The MPS is a field replaceable unit (FRU), there are no user serviceable parts. **The cream metal covers must not be removed.**

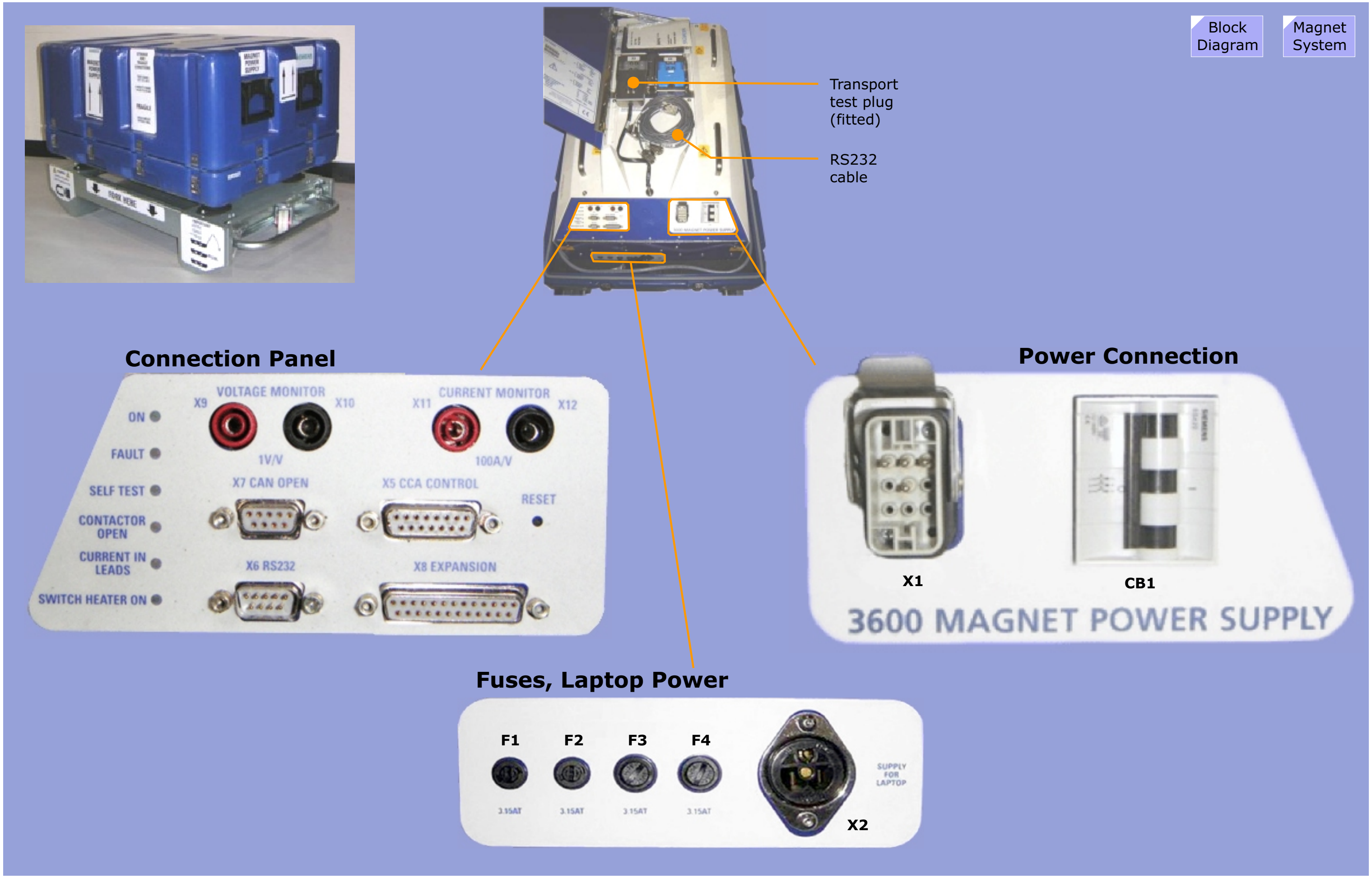
Maintenance is restricted to checking and replacing fuses **F1** to **F4** on the front panel, and external cleaning, using a slightly damp cloth. If the MPS fails to operate, it must be returned to a local tooling centre for repair, and a replacement obtained.

Handling and Storage

The module may be stored in an environment as follows:

Parameter	Specification
Ambient temperature	-20 °C to 55 °C (-4° to 131° F)
Ambient pressure	700 to 1060 mbar (10 to 15 psi)
Relative humidity	40 % to 80 % non condensing

Figure 258 *Magnet Power Supply Connections*



Function

Communications

Two types of communication links are provided:

- **CAN** - fro communication to the magnet supervision unit
- **RS232** - for menu-driven software control

Power

The 400 VAC 50/60 Hz 3-phase line voltage is fed via **CB1** to a line filter. Two phases are supplied to transformer **T1** primary over fuses **F3** and **F4**. T1 secondary output, fused with **F1** and **F2,** is used for feeding an internal logical power supply, fans, output contactor and a power outlet for a laptop.

Control Circuit

The control circuit monitors and controls the operation of the MPS. Ramping commands issued by the operator are performed fully automatic by the MPS. Magnet-specific data required by the controller is obtained directly from the Magnet Supervision (MSUP) via the CAN-bus connection **X7**. If the CAN-bus is disconnected, the MPS is inhibited and the fault is displayed at the host or Service laptop PC.

Ramping Power Supply

The 3-phase input is rectified and regulated via a MOSFET switch and available at output connectors **X3** and **X4** (max. 725 A @ 12 V).

Run Down Load, MOSFET switch

To de-energize the magnet the energy stored in the magnet coil is applied to and dissipated by diodes in the Run Down Load (RDL) which are embedded in heat sinks and cooled by fans.

Shorting Contactor

The MPS is equipped with a shorting contactor that is normally closed. During different ramp phases, the control circuit will open the contactor when:

- the MPS ramps up the magnet
- the MPS ramps down the magnet

NOTE	Should the MPS shut off during a ramp (up or down) the magnet current will safely run down via the ramp cables and closed shorting contactor.

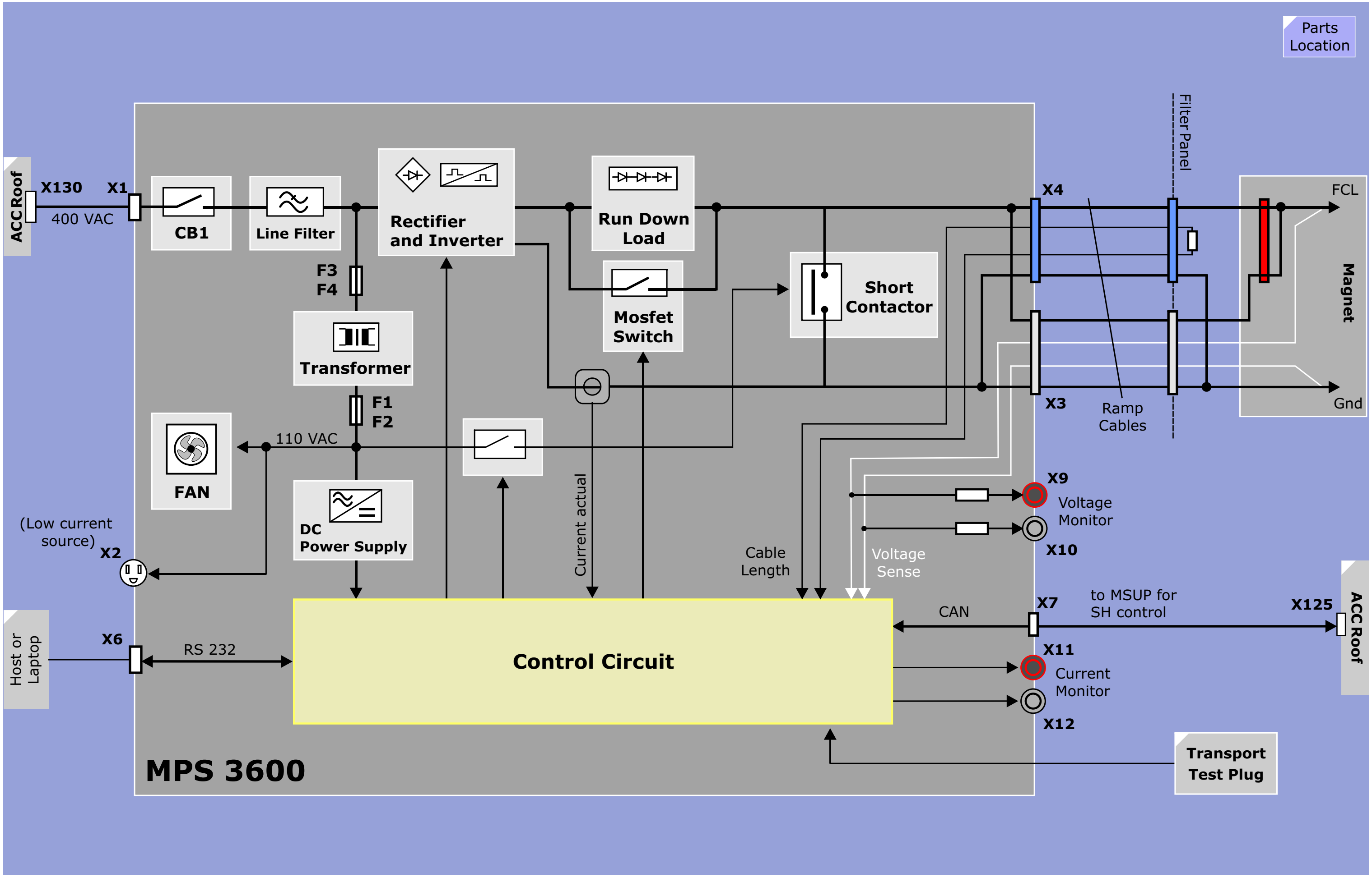
WARNING	**Risk of electrocution. Failure to observe the following safety warning may result in physical injury and equipment damage. If you suspect power is flowing in the ramp leads, DO NOT DISCONNECT THE RAMP LEADS from the MPS or the magnet.**

Actual output current is measured by a current transducer and can be measured at connectors **X11** and **X12**.

Current/Voltage Monitoring

The MPS output current and voltage are monitored by the Control Circuit. It is reported via RS 232 to the host or Service laptop PC. Additionally, a DVM can be connected to the voltage monitor terminals (**X9, X10**) or current monitor terminals (**X11, X12**) on the MPS connector panel.

Figure 259 *Magnet Power Supply 3600 Block Diagram*



Initialization

When the MPS is switched on (at **CB1**), a 'boot up' screen is displayed. Operator initials are entered.

The MPS retrieves the **magnet type, magnet serial number, last set current, He level, date** and **time** from the MSUP.

Transport Test

To check for internal MPS damage after transportation, a **Transport Test** can be performed by the operator. The test is only required the **first time** the MPS used on site and is performed **prior** to connecting the ramp leads and using the MPS on the magnet.

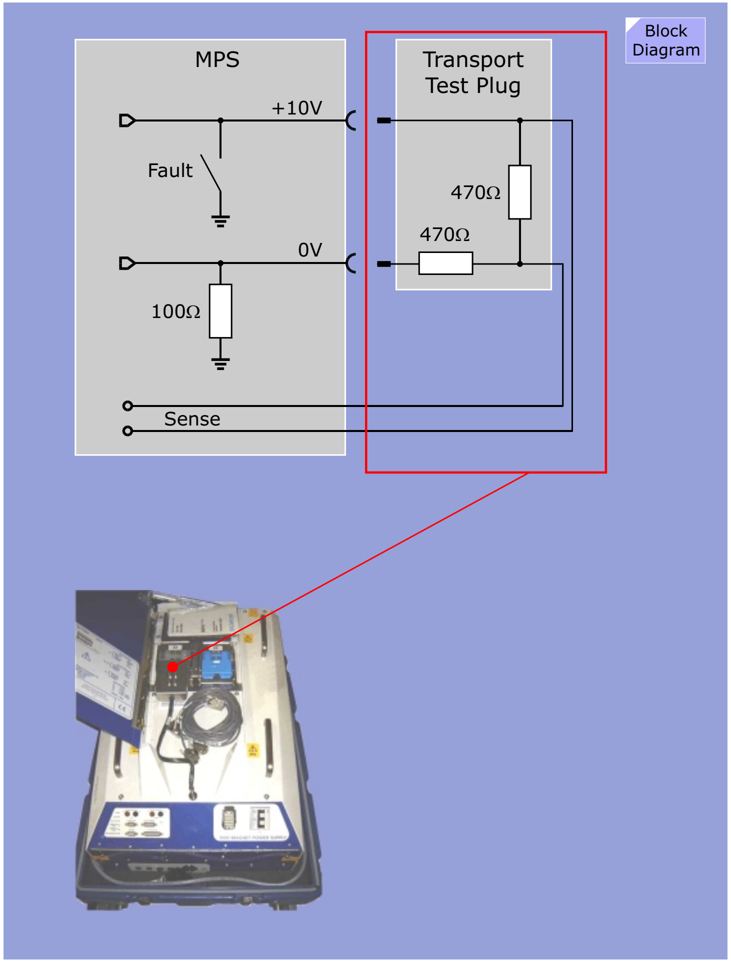
A suitable **Transport Test Plug** is supplied with the MPS, and the test must be **passed** before it is removed and the ramp leads connected. It consists of 2 x 470 ohm resistors housed in a grey Anderson (= company name) plug.

The center tap of the resistors is connected to a flying lead which is permanently bolted to the MPS chassis. Only 10 mA will flow and the fault can be determined by measuring at the voltage monitor test connectors X9 and X10, see Figure 259.

Table 2 *Transport Test fault condition*

Condition	Magnet voltage detected
-ve bus bar fault.	+ 9.5 V
Test passed	+ 8.5 V
Test plug ground lead not connected.	+ 4.7 V
+ve bus bar fault.	0 V
Test plug not connected.	0 V
Rundown load diode shorted to chassis	0 - 4.5 V

Figure 260 *Transport Test Plug*



Self Test

The MPS is run up to 700 A with the shorting contactor closed. The voltage drop across the MOSFET switch is monitored. When the current reaches its peak, the voltage is recorded (V1). Next, the MOSFET switch is opened and the current runs through the Run Down Load. Before the current starts to decay, the voltage drop across the RDL is recorded at Peak Current (V2).

Errors

If a fault occurs, an error screen is displayed automatically. To access it manually, the command "G" can be entered (see table above). The Magnet Peak Current is recorded on this screen, so if the magnet should quench, the level current at that time is stored.

MPS log file

The last ramp data is stored in a log file in non-volatile memory within the MPS, even if it is switched off. Data is overwritten when the next ramp is started. It is recommended that after each ramp, the log file is downloaded and stored for future analysis.

The Magnet Peak Current is recorded. If the magnet should quench, the recording will tell you at what current level the magnet quenched.

Array Shim Device

The Array Shim Device is a service and installation tool for magnet shimming and is not part of the delivery volume of the MR system. It consists of mechanical supports and a 50 cm diameter disk which can be rotated around the Z-Axis. To measure the field, the device must be positioned in the iso-center of the magnet.

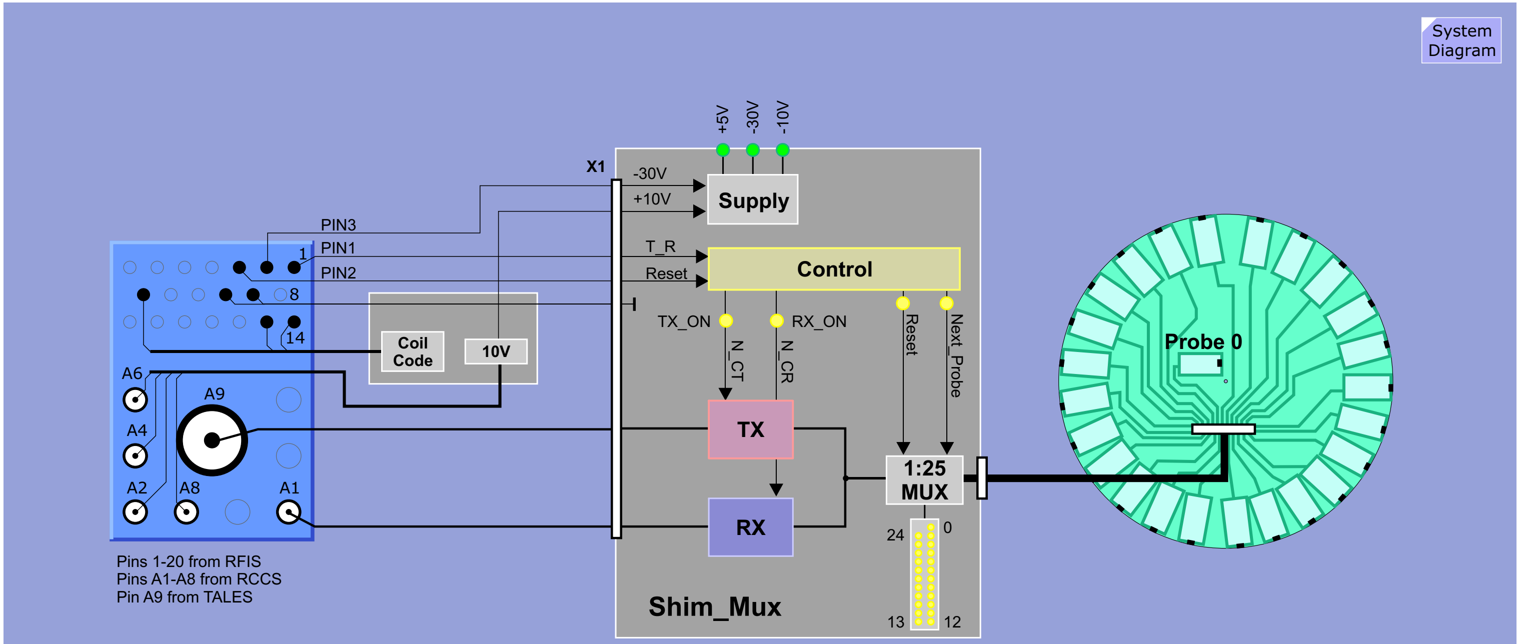
The disk itself contains 24 MR probes which are mounted on the outer diameter of the 50 cm disk. An additional probe in the center is used to determine the reference frequency at start of the shim plot. Each of these TX/RX-probes contain a sample with hydrogen protons; a simple FID-measurement is enough to determine the MR-frequency at each position precisely.

During the shim procedure, the service engineer has to rotate the disk by 360 in 20 steps, as a result 24×20 frequency values are acquired from the surface of the 50 cm homogeneity volume. From that data, the shim program can calculate the magnetic field inhomogeneities which are to be compensated with passive and active shimming.

Since there is a limited number of receiver channels on a coil pug, a multiplexer on the Array Shim Device is used to select the signals sequentially and feed it to coil plug no. 1. The addressing of the multiplexer is done by the RESET and T_R signal (see next figure). The selected channel can be seen by yellow LEDs at the front-side of the Array Shim Device.

The power for the multiplexer comes from the RFIS (-30 V over the coil plug) and from the RCCS preamplifier supply (+10 V). An additional +5 V voltage is generated by a regulator at the Array Shim Device. The presence of all three voltages is indicated by green LEDs at the front-side of the Array Shim Device.

Figure 261 *Array Shim Device*



Supply

The Shim Array device requires +5V for the control logic and -10V for the amplifiers. These voltages are generated from the +10V delivered over the receive lines A2 - A8. The -10V is derived from the PIN2 signal which is set to -30V. There are LEDs for the +5, -30 and -10 supplies.

Control

Signals PIN1 and PIN3 from the RFIS are being used as digital control signals. The T_R signal (PIN1) is used to generate the N_CT, N_CR and Next_Probe signals.

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Section

14 Changes

Changes in this version

Section 4 - Control System

Page 56 - added LED description

Section 6 - Patient Handling

Replaced all occurances of "Patient Board" with "Table Top"

Section 7 - Gradient

Page 171 - Impr oved F2/T11 connections in the diagram.
Page 195 - Modified text for jumper sttings X15.A4-B4 and X16.A12-B12

Section 8 - Magnet System

Pages 220, 221 - Added note stating OVC burst disk and vent will no longer be fitted.
Page 227 - Revised ERDU Button monitoring description and removed the statement about replacing the ERDU battery every 2 years.
Page 258 - Revised text on removal of gas lines from Cold Head

Section 9 - Cooling

Page 266 - revised Status Messages section and accompanying table

Version History

Same page references may no longer correspond those in this version due to the additions/changes of diagrams and/or texts in the older versions.

Version 5

Section 2 - Software
Changed all references of MRC into MRAWP.
Removed VB11 information (outdated)
Section 3- Host & Imager
Changed all references of MRC into MRAWP.
Section 7 - Gradient System
Page 185 - added switches S1 and S3
Page 189 - Correct text for Errors 0, 1, 7, 8, 10 and 15
Section 8 - Magnet System
Page 220 - improved MK2 schematic, added AVL burst disk
Page 221 - improved MK2 schematic, added AVL burst disk
Page 224 - New MSUP version supported
Page 232 - Correction to first paragraph: only 1x Link, 1x Bore can be displayed on MSUP display. To display the second set of Link and Bore sensors they would have to be jumpered on the MSUP.
Page 236 - corrected System ON/OFF circuit
Page 250 - Corrected Power Adaptation section
Section 9- Cooling
Page 265 - fixed voltage supply circuit on ACS controller
Section 10 - LPD
Page 278 - corrected position of X1.14 and connections of K3 contact to Alarm Box.

Section 12 - Dot Upgrades
New section. Replaces document M6-000.850.01.02.02 (Avanto Dot Functional Description)
Page 345 - Corrected connections on LWL and all footnotes
Section 13 - Service Tools
Page 355 - corrected siphon use table

Version 4

Section 2- Software
Page 15 - Removed material covered and regularly updated in syngo courses and/or in other documentation: DICOM, Database, Patient Browser, SRS
Section 3 - Host & Imager
Page 37 - Updated Host block diagram with new MOXA distribution, removed outdated material.
Page 40 - Corrected diagram: there are only 2 MOFIs per board regardless of PCI_RX version
Section 4 - Control
Added Gradient Supervision affecting the following pages:
Page 51, Page 60
Section 5 - RF System
Added links to Service Plug description on the following pages:
Page 95, Page 102, Page 122
Section 06 - Patient Handling
Page 168 - Added links
Section 7 - Gradient System
Added Gradient Supervision affecting the following pages:
Page 173, Page 195, Page 207
Page 201- Combined Power Stage Supply and D110 Power-Up diagrams and added jumpers on D70
Section 8 - Magnet System
Page 215 - changed Host RS232 port connection of MPS
Page 216 - changed Host RS232 port connection of MPS, correction of cable numbers W2039, W2002
Page 232 - Firmware change
Page 234 - revised text to Quench Detection LVQD sections
Page 253 - Note on removal of control connection
Section 9- Cooling
Page 273 - Updated SEP block diagram to reflect changes in SEP plumbing
Section 10 - LPD
Added Gradient Supervision affecting the following pages:
Page 280, Page 286 and Page 287(addition of X124)
Section 11 - Tune Up
Page 337 - Added diagram
Page 339 - Added diagram
Page 341 - Added description
Page 342 - Added diagram, warum auch immer.
Section 12 - Service Tools
New section, all descriptions of service tools have been removed from the respective sections to this section. The content is identical.
MPS, helium fill shiphon and MSUP display descriptions have been moved from Magnet section to this section
Array SHim device has been moved from the Tune_Up section

Version 3

Section 9 - Magnet System
Page 278 - chapter Alarm Box > Status Indicators > Alarm Buzzer - note added. CHARM MR_00398356.

Version 2

Section 8 - Magnet System
Magnet Supervision, description "Quench Detection (MSUP 2657B only)" added.
Alarm Box, description "Quench Alarm" added.
Alarm Box, description "Alarm Buzzer" added (CHARM MR_00398356).

rear cover